ISSN 1819-0146

CSCL 2007

The Computer Supported Collaborative Learning (CSCL) Conference 2007, Volume 8, Part 2

July 16 - July 21,
Rutgers, The State University of New Jersey
New Brunswick, NJ, USA

Edited by:

Clark Chinn
Gijsbert Erkens
Sadhana Puntambekar

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ISLS International Society of the Learning Sciences

CD-ROM, Part 2

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Rutgers University

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Volume 8

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Conference Co-Chairs:
Cindy E. Hmelo-Silver
Angela M. O'Donnell

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ISSN 1819-0146

Support provided by the Rutgers Graduate School of Education,
the Rutgers Department of Educational Psychology,
the Rutgers Center for Math, Science, and Computer Education,
the Center for Teaching Advancement and Assessment Research, and Drexel University

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Published by:
International Society of the Learning Sciences, Inc.
http://www.isls.org/

Printed Proceedings Printed and Distributed by:
Lulu
http://www.lulu.com

Printed in the USA

ISSN for CD-ROM: 1819-0146

Preface

CSCL 2007 marks the first time that the conference has been held on the east coast of the United States. It follows in the tradition of previous CSCL conferences beginning at Indiana University and continuing with conferences at the University of Toronto, Stanford University, University of Maastricht (Netherlands), University of Colorado at Boulder, the University of Bergen (Norway) and Taipei, Taiwan. It has grown over the years and become one of two flagship conferences of the International Society of the Learning Science. CSCL 2007 is being held at Rutgers, the State University of New Jersey. Rutgers, founded in 1766, is the eighth oldest institution of higher education in the United States.

The theme of the conference, *Of Mice, Minds, and Society*, explores interrelations among technology, individual cognition, and social cognition. The goal of the conference is to sharpen the community's perspectives on how these threads of CSCL are interwoven and how they interactively contribute to an understanding of the nature of learning in technology-supported environments. The community must engage in collaborative knowledge building to help understand the dialectical relationships among technology, collaboration, and learning. The theme denotes the relationship between the technological interface (*of mice*) that supports individual or group cognition (*of minds*). It also reflects the larger societal context in which collaborative activity is valued, promoted, and encouraged (*of society*). Collaborative activity that is supported by computing resources can achieve its potential to foster creative problem solving, build and extend community, and amplify the resources available to individuals or groups. The theme of the conference reflects our goal to explore how this potential can be achieved.

All papers went through a rigorous peer review process. For the long papers, the acceptance rate was 30%. Overall, 35% were accepted in the format proposed and 22% were accepted in another format. The proceedings contain 52 long papers, 102 short papers as well as descriptions of symposia, preconference events and doctoral consortium presentations. The program co-chairs did a Herculean task of organizing the review process for the 273 papers that were submitted. We thank the program chairs, Clark Chinn, Gijsbert Erkens, Sadhana Puntambekar, members of the program committee and all the reviewers who contributed to the high quality of the program.

The collection of authors is remarkably diverse in terms of country of origin, and disciplines represented. The papers themselves represent a wide variety of methodologies, and theoretical perspectives. We think that the proceedings reflects the diversity of CSCL researchers. Methodologically, papers represent research traditions that include design research, experimental, ethnographic, discourse analysis, social network analysis, conversation analysis, survey, and case study research. Authors come from disciplines that include cognitive psychology, computer science, communications, educational psychology, human-computer interaction learning sciences, linguistics, philosophy, social psychology, and education, broadly construed. At the last count before this went to press, there were participants registered from more than 25 different countries.

This conference was a long time in planning and we have learned many lessons along the way. We thank our students, colleagues, and family members for their support during the conference preparations. The proceedings would never have been completed without the dedicated work of Christina Yi Bo Zhang, Neha Mirchandani, and Yvonne Gonzalez. Our webmaster, Zhitong "Lin" Yang has worked tirelessly keeping the web site up-to-date. Special thanks to all the steering committee co-chairs who organized their pieces of the conference. We would also like to thank the Rutgers Office of Continuing Education and Global programs directed by Darren Clarke, and ably assisted by Paulette Flowers-Yhap, Johanna Rosa, and Kwesi Vincent. We thank our co-sponsors, Drexel University, Rutgers Department of Educational Psychology, the Rutgers Center for Math, Science, and Computer Education. and the Center for Teaching Advancement and Assessment Research. We also appreciate the assistance of the GSE's Office of Information Technology. We are grateful to the advice of those who have done this before and readily shared their wisdom: Gerry Stahl, Dan Suthers, Yasmin Kafai, Ken Hay, Janet Kolodner, Tak-Wai Chan, Tim Koschmann, and Chris Hoadley. Finally, we could never have done this without the support and encouragement of our colleague and Dean, Richard De Lisi.

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Computer-supported Collaborative Learning and Conceptual Change

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Abstract: Students often have difficulties achieving conceptual change in both individual learning and collaborative learning environments. Although research in the fields of both conceptual change and collaborative learning are well documented, few studies examine the relations between computer support and collaborative conceptual change. This review addresses this issue and considers the potential of CSCL for promoting conceptual change. We first review the major findings in the fields of conceptual change and collaborative learning. We then review literature on CSCL and discuss why CSCL environments may help in overcoming barriers to collaborative conceptual change. Finally, implications are provided for future CSCL design.

Introduction

There is broad consensus on the potential for computer-supported learning environments, particularly computer-supported collaborative learning (CSCL) to improve students learning (Goldman-Segall & Maxwell, 2003; Suthers, 2006). Although much research has examined whether computer-supported activities or collaborative activities are related to learning, less attention has been paid to the issue of whether computer-supported activities can foster collaborative conceptual change. The purpose of this review is to explore specific ways in which computers may offer powerful support for collaborative conceptual change in scientific domains. There are four sections in this review with the major focus on the last two: conceptual change, collaborative conceptual change, computer-supported conceptual change, and computer-supported collaborative conceptual change. The first two sections briefly introduce some major findings regarding individual and collaborative conceptual change. The third section will discuss the relationships between computer-supported learning and conceptual change. The fourth section is the core of this review: how collaborative conceptual change may occur with the support of computer-based instruction. We will use both theoretical and empirical evidence to consider the potential effectiveness of CSCL environments in fostering conceptual change.

Conceptual Change Theories

Conceptual changes refer to a process by which learners build new ideas in the context of their existing understanding (diSessa, 2006). In science education, the ideal conceptual change involves students' shift from their initial preconceptions to scientific conceptions (i.e., scientific beliefs, ideas, or way of thinking). Conceptual change is a difficult and complex process (Chinn & Malhotra, 2002). There is a huge diversity of perspectives about basic issues in conceptual change. Posner and colleagues (Posner, Strike, Hewson, & Gertzog, 1982) proposed a highly influential theory of conceptual change, which regarded conceptual change as linear and radical. Alternatively, diSessa (1993) believes learning is a gradual and evolutionary change in the way learners reconstruct their ideas and conceptions. Carey (1991) considers conceptual change as a process of enrichment (a form of weak restructuring) and revision (a form of strong or radical restructuring) of prior knowledge and interpretative frameworks. Regardless of the different theoretical perspectives on conceptual change, the common underlying theme is to investigate ways to promote such change.

There are two major categories of perspectives: Piagetian perspectives and the social constructivist perspectives. The Piagetian perspectives on conceptual change stress the importance of recognizing knowledge discrepancy in learners' prior knowledge and dissatisfaction with existing knowledge. In addition, this line of research regards the conceptual change process as either knowledge assimilation or knowledge accommodation. The cognitive conflict approach to achieve conceptual change typically involves evaluating learners' existing knowledge, presenting conflicting information, and re-evaluating, leading to changes in learners' conceptions. Thus one essential strategy that Piagetian perspectives recommend to foster conceptual change is to confront students with discrepant data or events (Chinn, & Brewer, 1993; Driver, Guesne, & Tiberghien, 1985). However, empirical studies show that even cognitive discrepancies often do not lead to conceptual change. Nissani and Hoefler-Nissani (1992) presented a study in which even natural scientists were surprisingly resistant to shifting their conceptions despite contradictory data.

Alternatively, social constructivist theories view conceptual change via the lens of social contexts and take into account the distributed nature of cognition. They follow Vygotsky's argument (1978) that all higher psychological functions (e.g. perception, voluntary attention) have social origins. This line of research views conceptual change as occurring through social interactions such as collaborative learning. Research consistently demonstrates that tasks that require learners to engage in active, constructive and integrative tasks lead to best understanding (e.g., Chi, de Leeuw, Chiu & LaVancher, 1994; Goldman, 1997). Collaborative learning can provide affordances for such engagement (O'Donnell & O'Kelly, 1994). For example, Chinn, Anderson, and Waggoner (2000) demonstrated that students who engaged in more argumentation-related behaviors developed better understanding from peer discussion than individual learning. Duschl and Osborne (2002) suggested that argumentation can be prompted by providing access to multiple accounts of phenomena and evidence and with a context to foster dialogic activity. Stressing the need to consider affective and social factors, Pintrich, Marx, & Boyle (1993) challenged Posner et al's (1982 original conceptual change model), which they called "cold" change. Instead, they developed the notion of "hot" or *intentional* conceptual change. All in all, the social constructivist perspectives particularly point out the importance of social interactions in the process of conceptual change. In the next section, we will elucidate how conceptual change takes place in the collaborative learning environment.

Collaborative Conceptual Change

Social constructivists argue that knowledge develops through social negotiation. Their assumption is that engagement in discourse promotes learning (Rogoff, 1990). First, peer interactions may lead students to restructure their existing knowledge. Roschelle (1992) reports a study in which convergent conceptual change occurred when students collaboratively used a computer simulation - the Envisioning Machine (EM) to learn about two physical concepts: velocity and acceleration. In the EM study, students restructured their commonsense ideas, to make meaning of a scientific concept. Students referred to the concepts of velocity and acceleration as the "thin" and "thick" arrows and successfully shared the meaning of these concepts by iterative cycles of displaying, confirming, and repairing meanings. Secondly, peer interactions may stimulate the need for knowledge revision. Duschl and Osborne (2002) suggest that opportunities for discussion and argumentation aids students in considering and evaluating other perspectives and thus may help learners revise their original ideas. Scientific argumentation usually involves proposing, supporting, criticizing, evaluating, and refining ideas. Peer collaboration provides a rich environment for mutual discovery, reciprocal feedback, and frequent sharing of ideas. Crook (1994) pointed out three major cognitive benefits of peer collaboration: articulation, conflict, and co-construction. The discrepant ideas from peers may require students to explain or reflect on and then compare their original ideas with alternatives from their peers, thus leading to eventual conceptual change. Finally, peer interactions may encourage deep mental processing. According to Chinn and Brewer (1993), deep processing includes attending to contradictory information, attempting to make meaning of alternative ideas, looking for evidence to support or dispute a theory, establishing causal relations between the evidence and considering the validity of evidence. In collaborative learning, students have the tendency to convince others by providing evidence to support their own theories and ask for evidence for alternative theories.

In summary, peer interactions may contribute to conceptual change by arousing an awareness of the need for knowledge revision, initiating knowledge reconstruction, and encouraging deep processing. However, there is no guarantee that collaborative learning will be productive and successful (Dillenbourg, 1999; O'Donnell, & O'Kelly, 1994). Barron (2000) found that it is necessary to find ways to help students achieve common ground when facing novel problems and coordinate efforts in collaborative activities. CSCL environments have the potential to help make collaboration more effective.

Computer-supported Conceptual Change

Research has shown computers are particularly effective in fostering conceptual change because in these environments, students can engage with simulated phenomena and review their actions as they formulate and test alternative hypotheses, receive feedback, and reconcile the discrepancy between their ideas and the observations (e.g. Beichner, 1996; White, 1993; Zietsman, & Hewson, 1986). Beichner (1996) proposed that technology-based instructional approaches could allow for an examination of interactions and collisions that is more direct and obvious than with traditional laboratory methods. In his study, 368 introductory physics students in a variety of instructional settings used a video analysis software package - the *VideoGraph,* which allowed students to compare videos directly with synchronized, animated graphs and to measure slopes and areas on the graphs. The outcome of the post-instruction assessment of students' ability to interpret kinematics graphs shows that students using this software performed better than those taught via traditional instruction. Zietsman and Hewson (1986) investigated the effects of instruction using computer simulations along with conceptual change strategies. They showed that computer simulations may highlight when students' current conceptions are not adequate and thus promote conceptual change.

Computer-supported learning environments may facilitate students in developing their metacognitive capabilities. Computer technologies provide explicit cognitive models to help students' planning, monitoring, revising and reflecting. For example, ThinkerTools promoted students' metacognitive ability to plan, monitor and reflecting during scientific inquiry in addition to helping students learn physics concepts (White, 1993; White & Frederiksen, 2000). The ThinkerTools curriculum focuses on the development of metacognitive knowledge and skills needed to create and revise their theories through an instructional inquiry cycle consisting of a motivation phase, model evaluation phase, formalization phase, and transfer phase. It provides a set of interactive simulations and modeling tools for middle school students to develop understanding of physical theories as they engaged in conducting experiments, creating and evaluating models, and revising the theories. Once they finally select the best theories and causal models, they apply them to different real-world situations by predicting and explaining what would happen. The results show that the alternative representations and models embodied in ThinkerTools helped students develop conceptual models that they could apply to solve physics problems.

In summary, empirical evidence shows that computer-supported learning environments may promote conceptual change in two ways: first, they can help students realize discrepancies between their original ideas and alternative ideas; second, they may provide affordances for developing students' metacognitive skills, such as planning, self-regulating, and monitoring. The research reported in this section examined individual conceptual change. In the next section, we discuss the role of computer-based learning environments in collaborative conceptual change.

Computer-Supported Learning and Collaborative Conceptual Change

Little research has attempted to examine CSCL environments from the perspective of collaborative conceptual change and show how and why CSCL may foster such change. In this section we provide both theoretical and empirical evidence to address this issue. The framework of analysis in this section is based on the obstacles that normally occur in the process of collaborative conceptual change and how computers may have the potential to help students overcome these obstacles. The theoretical analysis may shed light on the implications of future design of CSCL tools for the purpose of promoting conceptual change. To address this issue, we will first present two empirical studies that aimed to directly examine the role that computer-supported instructions play in collaborative learning. Then obstacles that occur in collaborative conceptual change will be discussed. Finally, we will discuss the potentials of CSCL instruction in the process of conceptual change. In general, computers have been used in two ways to promote collaborative learning (Hmelo, 2006). First, simulation and modeling tools create a context for students to test their conceptions and this context can provide a focus for negotiation. Second, computer-based discussion spaces can scaffold student reasoning and collaboration and provide opportunities for students to students to articulate their thinking, compare perspectives, and reflect on their learning.

Empirical Evidence

There are some empirical evidence supporting the idea that CSCL can promote student learning and conceptual change, such as Roschelle's influential study of dyads working with the Envisioning Machine discussed earlier (Roschelle, 1992). This use of computers falls into the first category: the EM provides a context for students to negotiate meaning and test their conceptions. Recall that this study investigated a dyad's collaborative conceptual change using a computer simulation. Based on these findings, Roschelle conceptualized collaboration as a process that gradually leads dyads' individual understandings to converge. The computer served as a medium for the dyads to establish the common understanding, which is critical for achieving collaborative conceptual change. However, collaborative conceptual change should go beyond knowledge convergence. Another example is the Force and Motion Microworld (FMM), a suite of computer simulation programs developed by Tao and Gunstone (1999). They examined high school students' collaborative conceptual development in physics. The findings showed that the FMM programs provided students with many opportunities for co-construction of shared knowledge through asking students to carry out predict-observe-explain tasks. Although there was evidence that students built on each other's ideas and reached shared understanding, not all students sustained their conceptual change after instruction. Only those students who were cognitively engaged in the tasks and prepared to reflect on and reconstruct their conceptions did obtain eventual conceptual change

Scardamalia, Bereiter, and Lamon (1994) also provided empirical evidence for the positive relations between CSCL and conceptual change while students worked with CSILE. The CSILE environment falls into the second category of tools that elicit articulation of ideas and scaffold building collective understanding. CSILE provides a networked community database where students can discuss ideas and build knowledge. The students must label their discussion notes using prompts that describe the role of the note (e.g., I need to understand, My theory). A series of studies indicated that students gain deeper understanding and collaboratively construct knowledge while working in CSILE environments compared with traditional classrooms in the depth of learning and reflection, awareness of what they have learned or need to learn. Moreover, students also achieved individual learning outcomes on standardized tests in reading, language, and vocabulary.

Vosniadou and Kollias (2003) used a computer-supported environment, the Web Knowledge Forum (WebKF; a descendant of CSILE), in which dyads constructed a model of the internal heating system of an average Greek house and explored how such a system works. Each student was required to keep notes of cognitive, metacognitive, and communicative activities. The results showed significant pre-post differences in understanding how a hot water heating system works but did not show gains in knowledge about heat and temperature in general. Interestingly, they found considerable metacognitive activity in dyads' conversations. Therefore, they concluded that CSCL environments can be helpful in developing metacognitive and intentional learning skills.

These empirical studies point out the important role of computer-supported learning environment in students' collaborative activities. However, they did not show how and why these CSCL environments can lead to successful conceptual change. Questions like whether and how computer-supported learning environments can foster collaborative learning remain unanswered. Therefore, we need to pay more attention to the specific roles that computers can play in fostering collaborative conceptual change. Furthermore, both studies indicated that collaborative conceptual change is beyond convergence of knowledge. There are several conditions that need to be met to achieve collaborative conceptual change, and these are difficult to achieve in many collaborative learning environments with no computer support. In the following section, we will address these issues through a theoretical analysis.

Theoretical Analysis

To present a theoretical analysis on how computers may provide affordances for collaborative conceptual change, we will first examine obstacles that normally occur in students' collaboration. We then consider evidence that CSCL environments have the potential to overcome these obstacles to collaborative conceptual change.

Obstacles to Collaborative Conceptual Change

Collaborative learning is not always successful (Dillenbourg, 1999; O'Donnell & O'Kelly, 1994). There are several obstacles in collaborative learning that need to be overcome to achieve collaborative conceptual change. Instructional techniques should provide affordances for overcoming these obstacles and promoting effective collaboration. First, the quality of dialogue or discussion is always a concern in collaborative learning. Deep processing is critical for conceptual change (Chinn & Brewer, 1993). If collaborative learning fails to involve deep processing or higher order thinking, such as attending to contradictory information, attempting to make meaning of alternative ideas, looking for evidence to support or dispute a theory, establishing causal relations between the evidence and considering the validity of evidence, the collaborative discourse may fail to promote deep processing. Chinn and colleagues argued that students often fail to change their theories because they 1) hold beliefs that cannot be integrated with the theory, 2) believe that some of the evidence can be explained by other implausible causes, or 3) cannot use the data presented to create a model of the phenomena (Chinn & Brewer, 2001; Chinn & Malhotra, 2002). Unfortunately, these same problems often occur in exchanges between students. Without scaffolding, collaborative discussions may remain superficial. Hence, instructional tools are needed to support learner's collaborative engagement in deep processing. More specifically, tools should support collaborative discussion that leads to making arguments on the basis of evidence and establishing causal relations between the evidence and one's perspective.

Second, according to classical conceptual change theory, cognitive conflict is regarded as essential to initiate conceptual change. One would expect that in collaborative discussions, there would be greater opportunities for conflict. Even though conflicts between individual ideas do not necessarily arise in peer collaboration, it is important to help arouse the within individual cognitive conflict by engaging students into reflection and accommodation of previous knowledge. Some research found that students seldom directly disagree with each other when collaboratively working on a problem due to politeness. Often, students even resist collaborative learning to avoid conflicts that might occur. There are two possible reasons for why students ignore the conflicts in their collaborative activity: either they may not realize the existence of alternative conceptions or they tend to take perspectives using different criteria to justify their ideas. If it is the first case, tools are needed to make the dynamic nature of scientific concepts explicit to students; if it is the second case, then students need to learn how to take a stance on the basis of experimental data or evidence. On the other hand, even if students clearly see the conflicts, they may resist conceptual change because people have a strong tendency to keep their original ideas. For instance, Chinn and Brewer (1993) proposed seven possible responses to anomalous data, only one of which is the adaptation of the theory on the basis of observed data. This indicates that students make arbitrary decisions when accepting or rejecting a theory. In accordance, Trumper (1997) also found that students reacted differently to conceptual conflicts that did not lead to conceptual change when learning about the energy concept. Some failed to recognize the conflict; some recognized but avoided solution by passively relying on other peers; some resolved the conflict partially; and some resolved the conflict using alternative conceptions. Tao and Gunstone (1999) asserted that "conceptual conflicts did not always produce conceptual change. For conflicts to lead to change, students need to reflect on and reconstruct their conceptions" (p.870). All these findings indicate that it is necessary to provide tools to help students realize the existence of alternative perspectives or even, if it is necessary, deliberately create conflicts in students' discussion thus prompt conceptual change. As well, it is also essential to provide appropriate scaffolding to facilitate student to learn how to make a decision on either accepting or rejecting theories on the basis of evidence. Only by reflecting on evidence and accommodating one's original ideas can conceptual change occur.

Third, the epistemic goals are rarely addressed in the collaborative learning (Duschl, & Osborne, 2002). The epistemic goals include aspects of what, how and why we know. These goals are critical for intentional conceptual change (Pintrich et al., 1993). Duschl and Osborne (2002) proposed that to enhance students' abilities to set epistemic goals, the instructional tools should focus on "(1) how evidence is used in science for the construction of explanation, and (2) on the criteria used in science to evaluate the selection of evidence and the construction of explanations." (p. 40). In collaborative learning, the epistemic goals may prompt students to change their ideas in response to evidence provided by others in the group. In addition, without knowing how and why they are learning, the students might just collaborate to memorize knowledge that remains encapsulated in a school context rather than co-construct knowledge that can be transferred to other situations. Hence, the conceptual change does not really take place for the purpose of conceptual change is to help students change their everyday life thinking by applying the scientific knowledge to explain phenomena and understand the world.

In summary, there are three major obstacles to achieving collaborative conceptual change: absence of epistemic goals, low quality of discussion, and inadequate skills to deal with competing ideas, all of which are essential aspects in the process of collaborative conceptual change. If the computer-supported tools can provide affordances to deal with these obstacles, computers may contribute to fostering collaborative conceptual change.

How Computers Can Help Deal with These Obstacles

Theoretically, appropriately designed CSCL environments can be powerful tools for overcoming obstacles to collaborative conceptual change by improving the quality of discussion, and providing scaffolding to facilitate student collaboration and working with alternative ideas, and making the epistemic goals explicit.

Improve the quality of discussion. Computers can mediate the collaborative discussion by focusing the discussion on the joint task and inspire deep processing. The computer screen offers highly shared focused objects for reflection and discussion. Students can avoid ambiguous language through images on the screen and establish common attention to referents within the discussion as occurred in Roschelle (1992) and Hmelo-Silver (2003). In addition, they can also test out alternative views. Hmelo-Silver (2003) conducted a study to examine how students constructed a joint problem-space. Groups of students were asked to design a clinical trial to test a cancer drug using the computer-based modeling tool, the OncoTCAP clinical trial wizard. In accord to Roschelle's findings, she found that even though direct conflicts rarely occurred in the group collaboration, students did tend to modify and refine their knowledge with the facilitation of the tools, which indicated that the collaborative activities within the computer-supported environment did help students realize the need to modify their knowledge base. Clements and

Nastasi (1988) found significant group differences among groups of students using Logo for conflict resolution, rule determination, and self-directed work. They suggested that it is the computer-assisted learning environments (e.g., simulation and word processing) that are likely to produce a greater frequency of quality interactions. However, it is possible that different software encourages different types of interactions amongst students (Crook, 1990). Wild (1995) investigated the verbal interactions of 12 students (9-10 yrs old) in four collaborative groups using simulation and word processing software. The simulation task involved the use of Terra Australis; students were given specific roles, encouraged to help each other and to make group decisions. The word processing task was to produce a combined report of the sailing adventure experienced while using Terra Australis. The results indicated that students' talk was more cognitively oriented when working with simulation software than when using the word processing.

King (1991) observed verbal interaction and problem solving behavior of small collaborative peer groups working on computer-based tasks. She found that successful groups engaged in more task talk than social talk. They ask more task-related questions, which were more strategic, and obtained higher elaboration scores than unsuccessful groups. Her study demonstrated that guided peer questioning in the computer-supported learning environment promote high quality peer interactions. Kozma (2000) concluded that computer-based technology can help collaborative interactions by providing symbolic elements and engaging students in focused inquiry that involves authentic scientific tasks. The combination of symbolic representations and inquiry activities enables and constrains the range of meanings by discourse, such that students can build on each other's ideas and intentions, draw new ideas into a common frame of meaning, and repair discrepancies.

In a follow-up to Roschelle's (1992) earlier study, Teasley and Roschelle (1993) examined how the EM simulation supported collaborative learning and thinking. In particular, the simulation provided a context that helped dyads successfully construct a joint problem space and share knowledge in the domain of Newtonian physics. They argued that the EM activity drew the emphasis away from the computer software per se and on to the quality of the dialogue. This study provided good evidence that dyads (15-year-olds) constructed a rich shared understanding of velocity and acceleration during a 45 min session using the EM. During that time, the dyads produced a lot of deep processing, such as exchanging ideas and explaining to each other, testing one's and each other's ideas in the simulation, making respectful changes judging by the validity of evidence.

In addition to deep processing, the quality of collaborative discourse largely depends on how much valid explanation, elaboration and argument is involved and how theories are evaluated. Webb (1989) conducted a meta-analysis which showed that the success of collaborative problem solving and learning depends largely on the level of elaboration of the information exchanged between the collaborating students. She concluded that group work with computers was beneficial and it was possible to design group-learning settings that benefited most students. Because computer-based simulations allow students to test their ideas, they are likely to confront with the discrepancies between observations and their originally conceptions. Beyond that, it gives students a rich context for discussion in which they can exchange and negotiate alternative perspectives (e.g., Hmelo-Silver, 2003). Computer-based learning environments can provide opportunities for students to elaborate their ideas, provide explanations, gather evidence to support their ideas or reject other alternative ideas as well as scaffolding evidence-based reasoning. Such opportunities may foster students' ability to use data to evaluate theories. In CSCL learning environments, students may use computer-based tools to test alternative ideas and the collaborative discourse can help individuals deal with the discrepancies between their conceptions and the available data. This affordance was illustrated in the example of the EM simulation (Roschelle, 1992; Teasley & Roschelle, 1993). The dyads were able to test out whether their ideas were correct or need repair. It the result of the testing did not support, they needed to negotiate until there understandings converged. Testing ideas was the most frequently strategy used to start negotiation in the EM simulation activity.

Make metacognitive thinking visible. The notion of intentional conceptual change brings attention to the role of students' metacognitive skills (Pintrich et al., 1993). Metacognition is the awareness and understanding of one's self as a thinker. Experts and effective thinkers tend to pose alternatives for themselves and choose among them by reflecting and using evidence. In contrast, students attempt to either accept without questioning or ignore alternative views. Therefore, approaches need to be developed to increase students' metacognitive awareness.

Traditional collaborative learning environment can make students thinking visible, CSCL environment can make collaborative thinking visible and can provide explicit support for students to construct arguments, engage in negotiation, and explain conceptual understanding. Most importantly, the techniques involved in CSCL environments afford helping student track their thinking process. The ThinkerTools is a good example of how computer-based environments may facilitate students to develop their metacognitive capability. White and Frederiksen (2000) report their findings of the instructional trials of the ThinkerTools Inquiry Curriculum in twelve urban classes in grades 7-9. Aiming at facilitating the development of metacognitive knowledge and skills that students need to create and revise their theories, the ThinkerTools incorporates a reflective process in which students evaluate their own and each other's research using a set of criteria that characterize good inquiry, such as reasoning carefully and collaborating well. They found that students who showed a clear understanding of the criteria produced higher quality investigations than those who showed less understanding. Their findings support that computer programs have the potential to introduce a metacognitive language to facilitate students' reflective explorations of their work in classroom conversations. Such metacognitive process may foster collaborative conceptual change by arousing an awareness of the need for revision of knowledge, initiating knowledge reconstruction, and encouraging deep processing.

In CSCL environments, electronic discussions provide affordances for students to engage in collaborative reflection. In a face-to-face classroom environment, the discussion might only benefit the few students who participate. The electronic environment allows universal participation. In addition, students have equal opportunities to respond to each other and engage in meaning making (Suthers, 2006). The electronic record is persistent and enables students to reflect on their own thinking as well as alternative ideas raised by other peer students. The CSCL environments can promote awareness of strategies for thinking by engaging the students in activities that require reflection. Students can keep and share a "thinking log" where they write down the thinking they employ in learning. As students share their entries, they gain an awareness of alternatives to their own processes. Activities like these, that require students to make the invisible work of thinking visible and explicit, help all students to visualize their thinking and alternative ideas. Hence, more purposeful, flexible, and reflective thinking is the result as the presence of other alternative perspectives available, which may prompt the process of conceptual change. Goldman, Duschl, Ellenbogen, Williams, and Tzou (2003) asserted that computer-based instruction might make thinking visible. They presented an example electronic environment, the Knowledge Forum (KF), which afforded to model the processes of coordination, construction, and evaluation to the students. Goldman et al (2003) found within the context of SEPIA project, which aims to promote scientific reasoning and communication, the KF entries "extremely valuable for taking the pulse of students' scientific thinking and argumentation approaches" (p. 278). They further implicated that there were some pragmatic constrains since the real application of the KF was somewhat different from what the creators intended. For example, the students only had time to make their own thinking visible but did not examine the entries of other students'. Another example CSCL environment is the KIE environment (the Knowledge-Learning Environment, the previous version of WISE). In the KIE, the SenseMaker tool makes it possible to help students see their thinking process when presenting argumentation (Bell & Davis, 2000). The SenseMaker helps students figure out the relationships between a numbers of Web resources by asking students to organize the information into categories and use them as evidence to make an argument. The Mildred tool in the KIE software provides conceptual and strategic hints to scaffold students' thinking. All these tools facilitate students to see their own thinking (Bell & Davis, 2000). Both KF and KIE illustrated that the CSCL environments have the potential to make students' thinking visible and enhance their metacognitive strategies.

Develop strategies to discover and resolve conceptual conflicts. Students have difficulties dealing with conflicts and need help realizing that there are competing conceptual explanations for phenomena. Sometimes it is even necessary to deliberately create conflicting perspectives so that students have chances to learn how to develop an effective argument in the collaborative work. For instance, in the KIE learning environment, students are asked to take one side of two conflicting hypotheses for the propagation of light. In this way, students need to explore sufficient experimental evidence to support the stance they take (Davis & Linn, 2000; Linn, 2000). Thus, the KIE software provides scaffolds for students to first realize the conflicting nature of scientific learning and to secondly learn how to resolve the conflicts by integrating alternative concepts. Although collaboration offers opportunities for conceptual conflicts to occur, when facing with such conflicts, students fail to reflect on why such conflicts exist and either ignore the conflicts or simply accept it without any support of evidence. Without such reflection, conceptual change is unlikely however collaborative learning settings may be more likely to promote such reflections as students compare their understandings and negotiate meaning.

CSCL environments can provide scaffolding to promote effective ways of dealing with conceptual conflicts. Student-initiated hypothesis generation is a central process in many computer-based learning environments and can help students to construct argument and produce conceptual conflicts. Computer-mediated communication offers the opportunities to structure learners' discourse in productive ways. Scaffolding and scripted collaboration can be operationalized by cues inserted into messages to help structure students' online discourse in productive ways. Weinberger, Fisher, and Mandl (2004) conducted a study investigating the effects of scripts on knowledge convergence in a computer-mediated communication learning environment. Each group of three learners was randomly assigned to one of the four experimental conditions in a 2 × 2 factorial design involving two factors: social scripts and epistemic scripts. Each group was asked to jointly prepare analyses for three case problems via web-based discussion boards. Two of the four conditions had the collaboration scripts implemented in the form of prompts inserted into the text windows of web-based discussion boards. The epistemic scripts supported the learners with their learning tasks by providing shared focus on the task, and the social scripts supported students to interact with each other by guiding them to share and contribute individual knowledge resources. The results showed that learners supported with epistemic scripts were highly convergent regarding focused knowledge during the collaborative phase but strongly impeded outcome convergence, the social script only slightly improved process convergence. These results indicated that different scripts in the computer-mediated environments may produce differential effects on knowledge convergence in collaborative learning.

A number of software environments that we have described involve scaffolding and scripts for argument construction including KIE (Davis & Linn, 2000; Linn, 2000), CSILE (Scardamalia & Bereiter, 1992), the Multimedia Forum Kiosk (Hoadley, Hsi, & Berman, 1995), Belvedere (Cavalli-Sforza, Weiner, & Lesgold, 1994). Grounded in research that has demonstrated the importance of argumentation in the process of conceptual change, all these tools aim to scaffold the development of students' argumentation and reasoning. KIE is a web-based environment that allows students to develop argument and use different sources of evidence to support their argument. CSILE is a communal database for building, articulating, and organizing knowledge. It facilitates students to set up hypothesis, search for knowledge and information to generate explanation and arguments to validate of falsify initial ideas. The Multimedia Forum Kiosk is an environment for discussion that makes use of multimedia for socially relevant representations, which allows the user to internalize and learn from the community knowledge base, and to construct knowledge by synthesizing new ideas. Belvedere is designed to support problem-based collaborative activities with evidence and concept maps. It has been assumed in all these computer-supported learning software that by laying out the relationships between evidence and arguments, students learn how to meet the needs to strengthen an argument.

Implications

To this point, we have discussed how computer-supported environments may promote conceptual change in the collaborative learning environment. We propose several implications for the design of CSCL environments to promote collaborative conceptual change. First, the focus of this review indicated three features of CSCL environments that may afford successful collaborative conceptual change. Designers should make efforts to include these features when designing a learning environment: scaffolds to improve the quality of collaborative discourse, make metacognitive thinking visible, and promote strategies to discover and resolve conceptual conflicts.

Second, it is critical to investigate and build on students' prior knowledge. In addition, it is also important to make the students themselves become aware of what preconceptions they hold. Bringing authentic problems or activities into the computer-supported learning environment may help fulfill this purpose. In this way, students have cues to activate their prior knowledge and connect it to current learning. However, the prior knowledge could either promote or impede the process of conceptual change (Pintrich et al., 1993). CSCL environments should give dynamic feedback to help students change their conceptions. One of the most importance strategies is to support students in generating alternative hypotheses, for example by providing the basic structure of a hypothesis as in BGuile (Reiser et al., 2003) which provides scaffolds for scientific inquiry in the domain of evolution. In addition, students' alternative perspectives are developed from experience and shaped by a socially constructed commonsense ways to describe and explain the world. CSCL environments need to include authentic activities and real world problems to connect to learners experiences.

Finally, as Goldman et al (2003) discovered that sometimes the CSCL tools are used differently from what the designers intend to. Therefore, much research needs to be done to investigate how to make full use of the designed tools and the range of more or less productive ways in which they can appropriated. CSCL tools themselves are not enough to promote collaborative conceptual change. Designers of CSCL environments need to consider the bigger context of how the tools will be used, the curriculum they will be used with, the participant structures, and the professional development for teachers who plan to use such environments.

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Enabling Organizational Learning through Event Reporting: A Case Study in a Health Care Context

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Abstract: Applying the organizational learning framework, we argue event reporting is an enabler for organizational learning in healthcare contexts in order to reach the optimal patient safety and care quality. The findings in this case study describe how the four different learning activities (intuiting, interpreting, integration, and institutionalizing) occurred in event reporting and suggest several challenges that need to be overcome before a health care organization can transform to a learning organization.

Introduction

In health care, continuous improvement of quality and patient safety has increased prominence since the Institute of Medicine report that estimates each year 44,000 to 98,000 people die of an iatrogenic injury, either as a main or a contributing cause, and that 1.3 million are injured by medical treatment. A key process in achieving patient safety is the ability to learn from errors. Within a healthcare environment the occasion of a safety event is also a learning opportunity for members and the organization. Not surprisingly, working in a hospital, health care professionals regularly encounter safety events that afford organizational learning opportunities; yet not many of these events are recognized as learning opportunity during the heat of the critical events (Naidu & Oliver, 1999). Therefore, many health care organizations and even some states have required health care professionals to report medical related adverse events as a means to monitor patient care quality and to learn from those events for future prevention. As a result safety event reporting systems are becoming critical parts of health care information systems.

Event Reporting as an Organizational Learning Process

In organizational development research, organizational learning (OL) is defined by the continuous development of knowledge and capacity, both individually and collectively (Senge, 1990). A learning organization provides continuous learning opportunities, promotes a culture of learning, uses learning to reach goals, and links individual performance with organizational performance ensuring individual learning and enhancing the organization as a whole. According to Argyris and Schon (1978), OL is a process of detection and correction of errors. In their view, individuals are seen as the agents of learning for organizations. In other words, OL is a multi-level dynamic process of continuous knowledge transformation and improvement in organizations. Crossan et al. (1999) suggested four main processes of OL. First, intuiting is the preconscious recognition of patterns and possibilities inherent in a personal experience. Second, interpreting is the explanation of an idea to oneself and to others through words or actions for building shared meanings and understandings. Third, integrating is the mutual adjustment, negotiated action, and shared practice among individuals. Last, institutionalizing is the process of formalizing actions from individual practices to the organizational routines. These processes are embedded in the workplaces and practices of organizational members, and collective knowledge is built through participation and negotiation of meaning among the members. Event reporting systems that invite participation and support communication and collaboration among the staff to resolve and learn from safety events have great promise for improving organizational learning and supporting patient safety.

In health care settings front-line practitioners spend the most time with patients and are most likely to observe safety events. These practitioners, against human and social barriers about reporting safety events, must feel free to report events and be supported in working with managers to identify root causes and safety solutions. It takes a cooperative team to construct a safety culture and to prevent errors from happening again. Collective knowledge and organizational learning are developed through member interactions that include negotiation of meaning. Technology can, and perhaps must be used in hospital settings given the time, distance and role separation inherent in hospital staffs, to mediate and support these interactions by providing timely information, facilitating communication processes, and supporting coordination and cooperation process among members regardless the physical barriers. Additionally appropriate design can turn these interactions into collaborative and organizational learning opportunities. The purpose of this study is to build new knowledge about how health care professionals collaborate in knowledge building for organizational learning and enhancing patient safety as well as in what ways information technology can influence the process of organizational learning.

Methodology

This case study was conducted in the context of University of Missouri Healthcare (UMHC), that in 2000 developed the electronic event reporting system, Patient Safety Network (PSN), to support healthcare safety. PSN is a web-based application that allows users to include general comments while reporting specific safety-related events. After an event submission, the report is directed to the responsible departments for review and resolution. PSN has been implemented for four years, and it has proven to be a successful system for reporting events (Kivlahan, et al., 2002). In 2005 a design effort was begun to advance PSN from simply a reporting system to a more collaborative problem resolution system with hopes that the new focus could facilitate a stronger culture of safety and support individual and organizational learning for promoting patient safety. A qualitative research design is used to best understand the healthcare context and the ways that healthcare professionals collaborate for knowledge construction in their work practice and activities. The target population included staff members who had event reporting or resolution responsibility, such as managers, staff, etc. In order to rapidly collect rich information of healthcare professionals' experiences, a purposeful sampling approach was chosen. The sampling criteria were the self-reported participation in PSN and the work locations. Two types of areas (ancillary and direct patient) were selected for participation. A total of 12 participants (4 managers and 8 general users) were recruited in four different units. Two individual semi-structured interviews asked the participants to talk about their use of PSN with two months apart. The interim period allowed the researchers to examine the first responses for the follow-up interviews. In the interest of finding the common themes and critical elements, the OL framework was used as a lens for data analysis.

Results

Intuiting of Event Reporting through PSN

In general, managers were the most frequent users of PSN as they regularly used it to resolve events while general users use it irregularly to report events that arose infrequently. Both managers and general users recognized the benefits and new opportunities of PSN for event reporting and resolution over the old paper-based system. Moreover, they also appropriated PSN for other patient related activities beyond event reporting. For example, some participants discovered ways of using PSN to seek expertise or help from outside their unit for problem solving.

Interpreting and Sense Making through PSN

Participants expressed a belief that the use of PSN had improved the efficiency of coordination and communication among individuals and departments for event reporting. Moreover, they found that by submitting an event to PSN, that some professionals in the UMHC who had knowledge, expertise, or resources became engaged to help solve the problem. This result demonstrated an innovative individual learning in PSN for accessing knowledge and expertise from the right people at the right time. However, most meaning negotiation among individuals, such as event investigation and discussion, took place outside PSN. Overall, PSN served as a trigger for initiating more face-to-face or other online communication and discussion but not as an effective mechanism. The implications seem to be that to the extent that communication and collaboration could be supported in PSN that would cut down the costs of using other mechanisms, replicating information that was already in PSN, and create a more complete report of the problem and resolution, which is the foundation for establishing the common ground among individuals.

However, some controversy was reported. Some participants wanted to have anonymous reports, while others argued that showing individual's identity could help establish validity and credibility for an event. Furthermore, managers felt that anonymous reports hindered the meaning negotiation process due to lack of communication and follow-up available under this type of circumstance. Another barrier for building a common understanding about an event is the lack of feedback returned to individuals and that contributions of submitting reports were not well recognized. Many participants saw event reporting as not just something to which they impersonally submitted an event, but rather they felt eager to know the details of what happened because of their submission and to learn how best to deal with the situation in the future. They expressed strong needs for active involvement and engagement in the process of resolution. With a strong intention for active participation and contribution, the lack of feedback or unclear responses seems to be a major limitation that hinders their participation and ability to learn from event reporting. The participants described that when they could not get the feedback they hoped for from the PSN they would turn to other means (email, phone, etc.) to obtain the information that they thought would be helpful and meaningful to them. Moreover, the status that no contributions were recognized or acknowledged by others frustrated the participants, especially when they showed strong intentions to contribute their professional knowledge to help solve a problem. A participant said "Especially when I put in a suggestion about what I think would fix the problem. I look at the list and I look at everyone's resolution, and no one even looks at it or it looks like no one even looks at my suggestion. My suggestion doesn't get seen. That is basically blown off. That's frustrating for me."

Integrating of Patient Safety Practice through PSN

Managers expressed PSN facilitated the negotiation of meanings and helped build common ground among departments as they strove to build a complete picture of an event though sharing information. A manager said "I add their side of story to it, and then that's the nice part when I go in to look at any resolution all the departments that are included, look at what they put in there so I can see their side of the story. And, sometimes it helps you understand the whole thing in order to help you decide: Hey! We need to get together to look at this further". Event reporting also provided a chance for managers to discover potential problems for timely training, education, and prevention. However, some challenges were reported when trying to develop collective actions for event reporting and resolution. The lack of integration with other applications was a barrier for building shared work practice and making mutual adjustments in work activities. The participants explained they had to hunt down several different applications and charts to get the information needed for reporting and resolution. Also the hectic and distributed nature of the healthcare work limited the time and effort they had for developing the shared patient safety practice.

Institutionalizing of Patient Safety and Learning Culture

The participants thought of themselves as members of the hospital so they wanted to contribute to positive changes and improvements in the hospital. There were several factors reported that hindered the institutionalization of a blame-free and learning culture. Key among these factors is the lack of feedback from the organization to the contributor. Thus, the participants did not understand in what ways and to what extent their reporting and resolution helped the organization grow and move forward. A manager said "Staff don't realize that they put a PSN in and something good comes up of it". The participants were not sure how the reports were used for improving health care quality and enhancing patient safety in the hospital. Similarly, managers also explained that they did not have hospital-wide information that can help them make a higher level solution for patient safety. The lack of feedback limited the formation of learning culture as well as the institutionalization of patient safety practices in the hospital.

Discussion and Conclusion

Several lessons are learned in this study. First, the current PSN has helped make reporting and resolution more efficient and effective by capturing information and supporting flow and coordination. It seems to have positively impacted intuiting, interpreting and integrating, even if only in small ways. Second, while PSN has potential to support some levels of social interaction among users to date it is experienced more as a documentation tool. Third, the participants expressed interest in building personal knowledge and contributing to organizational learning, but the lack of collaboration within PSN made that challenging, and the lack of feedback on submissions frustrated and thwarted the good intentions of the members. Without the ability to interpret and negotiate meanings among individuals, they feel their participation and hence knowledge building ends right after they enter the event data. Fourth, a dynamic tension exists between privacy concerns and recognition of contribution. Fifth, due to the lack of feedback from the departments and the organization, the participants had no sense of collective organizational knowledge being built and no learning cycles of activity were developed for the reporters to advance their knowledge and support organizational performance. To complete the dynamic OL process, feedback is required during the process and the design of information technology must take it into account.

These lessons suggest that the PSN redesign for making greater contribution to OL needs to implement support for collaborative learning, such as feedback and integral communication. Further the redesign should invite members to identify themselves, but respect that in some situations that are not desirable for them. Only in doing so will PSN support individual performance, build collective knowledge, and ultimately improve organizational performance. From an OL perspective, event reporting and resolution can be characterized as an intense knowledge construction activity that can connect healthcare professionals to continuously communicate with each other and learn from events while sharing knowledge and expertise, and to construct a medium which can promote a safety culture in organizations which in turn helps the healthcare organization improve patient safety and care quality.

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About the Complexity of CSCL Systems

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Abstract: CSCL systems must deal with both the general complexity of supporting people doing things collaboratively through computers and the specific complexity of constructing artificial situations in which collaborative learning processes are expected to occur. This paper emphasizes three high level requirements for designing-in-the-large rich and malleable CSCL systems dealing with that multiform complexity. For each requirement the paper describes solutions taken from the Omega+ effort for providing a generic and flexible synchronous CSCL framework.

Introduction

Technology-supported collaborative learning systems are intrinsically complex. They must deal with both the general complexity of supporting people doing things collaboratively through computers and the specific complexity of constructing precise artificial situations in which collaborative learning processes are expected to occur. Simplistic tools which support a single task in a predefined situation, which are not adaptable to different conditions, which suffer from restrictive constraints for installation and use, cannot expect to be largely adopted in real learning settings. During the previous CSCL Conference, future technologies were characterized as “richer and appropriate for various collaborative settings, conditions and contexts” (Dimitracopoulou) and “reconfigurable, adaptative, offering collections of affordances and flexible forms of guidance” (Suthers). Just providing a collection of artefacts and mechanisms that have been demonstrated to be correlated with effective learning in different contexts, in a ‘Swiss Army Knife’ style, is not sufficient for dealing with these complexities. CSCL support requires sophisticated and powerful *integration, customization and evolution technologies*. This paper emphasizes three high level requirements for designing-in-the-large rich and malleable CSCL systems. Each section briefly introduces a requirement, mainly in the light of Activity Theory (AT), and describes possible solutions taken from the Omega+ effort for providing a generic and flexible synchronous CSCL framework (Lonchamp, 2006).

A Reflective Architecture

AT explains that the structure of any cooperative activity is dynamic and continuously evolves. Tools alter the activity and are, in turn, altered by the activity (Jonassen & Rohrer, 1999). A computerized supporting system is a mediator which should continuously reflect the current structure of the supported activity. The most obvious way to achieve that conformance is to provide a *reflective system*, i.e. a system which includes an explicit representation (model) of the activity. The behaviour of such a reflective system depends on that (continuously queried) representation and changes when the representation is modified, thanks to the causal relationship which is implemented between the activity model and the system behaviour. Modelling cooperative learning activities both for human and machine interpretation is a big challenge in this approach. In the broader e-learning field, IMS Learning Design multi-level meta-model has been criticised both for its complexity and for its incompleteness (e.g., for dealing with synchronous collaborative activities). The solution explored in Omega+ associates a separate (sub-) model for each *facet* of a collaborative learning activity: process model, interaction model, artefact meta-model, and effect model. It makes possible to build the activity representation at different levels of abstraction, adapted to the skills and needs of different categories of users: just reusing existing models, building new combinations with existing sub-models (i.e., following a very high level configuration process), defining or customizing sub-models through high-level visual languages or low-level specification languages (including programming languages).

Process model: AT highlights the importance of *plans* for guiding work (Bardram, 1997). A plan is not a rigid prescription of work to be performed but a guide that can be modified depending on context during the execution of the work. In Omega+ a synchronous process is a sequence of phases, taking place in rooms: ‘simple phases’, where all participants collaborate to the same task in the same room, and ‘split phases’, where participants are divided into parallel sub groups performing different tasks in different rooms. A plan A→B→C does not necessarily prescribe the execution of the three phases A, B, C in that precise order. ABBC, AB, AB’C (where B’ is a modified version of phase B), ABCBC are other possible execution traces, while CBA and CCC for instance have a lower probability to occur. Concretely, participants playing the predefined ‘Room Operator’ role have two buttons for selecting the next phase to execute, either by following the plan (Next) or by selecting any other existing phase (Jump).

Interaction model: interaction protocols implement specific discourse types relevant in collaborative learning situations. In Omega+, the set of predefined generic protocols (such as 'round-robin', 'single speaker', 'moderated free floor') can be extended with application-specific protocols. These specific protocols are defined through a set of application-related roles, a set of typed messages, a set of adjacency pairs specifying how messages types are related (e.g. question-answer) and which role can speak first. Process and interaction models together implement *scripted cooperation* as defined by O'Donnell and Dansereau (1992), i.e., a set of interaction rules and phases according to which the cooperation proceeds in order to improve the effectiveness of cooperative learning.
Artefact meta-model: another important requirement for effective collaborative learning is the combination of communication with shared work artefacts (Suthers & Xu, 2002). Omega+ provides both predefined tools (shared text editor and whiteboard) and a *generic graphical modeller for graph-based hierarchical representations* that can be customized by selecting predefined artefact meta-models or by defining application-specific ones.
Effect model: effective collaborative learning requires coaching collaboration as it unfolds. The coaching process includes a data collection phase, a phase where high-level indicators are computed, a comparison of the current state of the interaction with the desired state, and a phase where remedial actions are proposed (Jermann et al., 2001). In Omega+, users can specify into 'effect models' customized visual indicators (e.g., time series, histograms) of individual and collective performance, computed from a set of predefined low level variables. Users are expected to analyze these *customized meta-cognitive tools* for devising remedial actions such as modifying plans and protocols.

Definitional, Operational, and Developmental Malleability

In AT, subjects drive evolutions for resolving *contradictions that appear during the course of the activity*. These evolutions impact the computerized support and put a strong requirement on *dynamic (run-time) malleability by end-users*. Malleability of computerized systems is considered as a difficult issue, because the more efficient mechanisms are also the more difficult to use and many users are not willing to make the efforts necessary to use them. We distinguish three kinds of malleability.
Definitional malleability: reflective systems, as defined in the previous section, provide this kind of malleability. The system can be statically (i.e., before execution) fine-tuned for various different settings, conditions and contexts, by including in its model(s) a selected choice of structural constraints.
Operational malleability: flexibility at run-time includes both dynamic model evolution and exception handling. In the case of model evolution, a change may impact only the enacting model or may also impact the template model in the model library. In Omega+ room operators can change interactively the enacting process model (e.g., change an existing phase type or add a new one). Changing template process models should be a collective decision and is discussed in the following section about meta-level support. In the case of exception handling, users with the corresponding rights can dynamically relax or sidestep a given constraint without changing the model itself. The system should be in charge of making other users aware of these rule breakings. In Omega+ predefined operations are provided for handling simple exceptions. For instance, if a learner cannot take the floor during a phase including a 'round-robin' interaction protocol, a menu item allows the room operator to skip to the next learner in the circle.
Developmental malleability: some changes, such as integrating external components that must communicate with other components through specific event types, cannot be performed without modifications at the code level. An example is discussed in (Lonchamp, 2006). In the last version of Omega+, end-users with basic programming skills, can also statically add operational semantics to graph formalisms (like Petri nets or state machines) by writing dedicated java classes that complement the declarative artefact meta-model.

A Comprehensive Meta-level Support

AT recognizes the existence of *meta-activities and meta-processes*. For instance, Bardram (1998) defines a 'co-construction level' where subjects *collectively reconceptualise their activity*. If the scope of meta-activities is restricted to the dynamic evolution of the environment then only a meta-interface is needed, i.e., a set of meta-operations that can use all dynamic malleability techniques previously discussed. Following the idea that "CSCL is a socio-technical process which requires careful planning and preparation by both students and teachers" (Carell et al., 2005), Omega+ gives a broader definition to the meta-level and focus on *cooperative meta-processes* for: (1) designing the learning situation and customizing the CSCL system, (2) monitoring the learning process and dynamically evolving the CSCL system, (3) post-analysing learning process results for further improvement of the situation and CSCL system, (4) supporting the pedagogical development of teachers within a community of practitioners. Three of these cooperative activities (1, 3 and 4), mainly asynchronous, stay clearly outside the scope of Omega+ synchronous system. The proposed solution is to provide a broader *collaborative web platform dedicated to CSCL practice, evaluation, and dissemination*. This platform, called ESCOLE+, aims at hosting virtual communities of volunteer teachers, CSCL specialists, and students for designing, executing, and tutoring Omega+

based CSCL sessions, analysing them, and debating all related technical and pedagogical issues. The underlying open-source cooperative infrastructure developed in our research team (www.libresource.org) provides to its users a tree of projects and sub-projects, each project including a tree of documents and resources such as wiki pages, forums, issue trackers, mailing lists, news, download areas, surveys, versioning tools, user groups and roles, timelines (event lists), etc. End users can create, delete, move and modify resources and projects. Each project has its own security policy and access rights can be defined individually for each resource and role. New projects can be created resource by resource or by instantiating templates, i.e. predefined resource sub-trees. The generic modeller of Omega+ has also been customized for generating these templates from high-level visual models. ESCOLE+ provides three main spaces (projects): a 'Pedagogical Space', including a 'Community Space' for general information exchange and a 'Design Space' where Omega+ models are designed by teachers and CSCL specialists within dedicated sub projects, a 'Learning Space', where tutors and students execute model-driven collective learning processes within specialized sub projects, and a 'Platform Space', for managing users, groups, documentations and so on. This platform, still under development, complements Omega+ in three domains. First, ESCOLE+ provides web support for hybrid processes mixing synchronous and asynchronous activities, like other systems such as KnowledgeForum or Synergia. Secondly, ESCOLE+ centralizes detailed usage information, through Omega+ logs and ESCOLE+ event lists, making possible usage analysis for long periods of time and for different contexts. Finally, ESCOLE+ can support the pedagogical development of teachers within a community of practitioners: newcomers can learn by observing ongoing processes (in a similar way of what happens in open-source communities), by replaying recorded processes, by reading experiment reports and best practices catalogues, by communicating with CSCL specialists and other interested teachers. Later, observers can start to participate to collective learning activity definition and design. Finally, they can tutor activities with their own students or other students, possibly with the help of more experienced teachers at the beginning.

Conclusion

This paper proposes a set of high level requirements for designing-in-the-large realistic CSCL systems dealing with the general complexity of supporting people doing things collaboratively through computers and the specific complexity of creating pedagogical situations in which collaborative learning processes are expected to occur. A reflective architecture, providing definitional malleability, is complemented by mechanisms for operational and developmental malleability. Specialized modelling approaches, high-level visual modelling languages and cooperative meta-level support are other basic ingredients required for allowing teachers, who are not computer experts, to perform themselves customization, evolution, and improvement meta-activities. However, new research efforts following an iterative and experimental design process, will be needed for designing-in-the-small the rich and malleable systems the CSCL community is asking for.

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Do internal factors of cooperation influence computer-mediated distance activity?

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Abstract: On the one hand, researchers have studied factors that influence collaboration and on the other, researchers have proposed models of collaborative problem solving. However, we have not found research on the relation between these factors and the dimensions used in order to describe the collaborative activity within the models. This article's goal is to propose such relations for a situation of collaborative design, mediated by computer and carried out at a distance. We will show two main relations that emerged from our corpus. Firstly, dialogue utterances between partners that have a dominant social aspect are positively related to the symmetry of the entire dyadic interaction in terms of partners' contributions. Secondly, dialogue utterances that predominantly deal with expressing what partners are doing is negatively related to the extent to which partners are aligned. This research also extends the field of applicability of the cooperative activity model proposed in Baker (2002).

Introduction

The models of cooperation elaborated in domains dealing with problem resolution aided by computers focus on a variety of phenomena. For example, they address spatial aspects of virtual worlds (Benford, Bullock, Cook, Harvey, Ingram & Lee (1993), decision processes carried out through a distributed information system (Gachet & Haettenschwiler, 2003) or forms of cooperation as reflected by dyadic interactions (Baker, 2002).

This last model of cooperation — the only full-fledged model amongst those cited above — is interesting in that it distinguishes different forms of cooperation within a dyad. Making these forms explicit helps us to understand how participants organize themselves when they solve a problem together. This organization is a function of the dimensions of activity that make up the model. From the moment that these forms are defined, it becomes possible to evaluate which of them characterize those interactions that are favorable for learning (Jakobsson, 2002; Burton, Brna & Treasure-Jones, 1996; Baker, 2002). Alternatively, it becomes possible to study which forms of cooperation would produce a final product of greater quality, for example in the case of design. But on which basis should we choose the dimensions of activity that are used to elaborate the forms of cooperation? And what factors can be related to these dimensions and in consequence, influence the forms of cooperation?

A model of cooperative activity and factors influencing cooperation

In the conceptual model of cooperative activity during problem resolution described by Baker, (2002), three principal phenomena appear upon observing people that work together: 1) different responsibilities and contributions, 2) the way in which people carry out their work together (e.g. each person's speed, mutual understanding), and finally 3) the presence or absence of agreement. The objective of Baker's model is to establish a link between cooperative activity and learning through the combination of three fundamental dimensions: role symmetry, alignment and agreement. (cf. Table 1).

Table 1. The fundamental dimensions of Baker's (2002) model of forms of cooperation

Dimension	Definition
Degree of symmetry	For a given continuous sequence of interaction, the similarity or difference in the responsibilities of participants in regards to the accomplishment of sub-tasks, such as is manifested in verbal or non-verbal communication, linked to material resources.
Degree of agreement	The difference in propositional attitudes (belief, non-belief, acceptance, non-acceptance) that are manifested publicly, in relation to the different aspects of cooperative activity of problem solving (solutions, goals, methods, actions).
Degree of alignment	The extent to which partners are "in phase", in relation to aspects of their cooperative problem solving (phases, degree of mutual comprehension, conceptualization of problem).

In the case where the values of the dimensions are binary (e.g. symmetrical / non-symmetrical, etc.), the three dimensional space corresponds to eight specific forms of cooperation (cf. Figure 1).

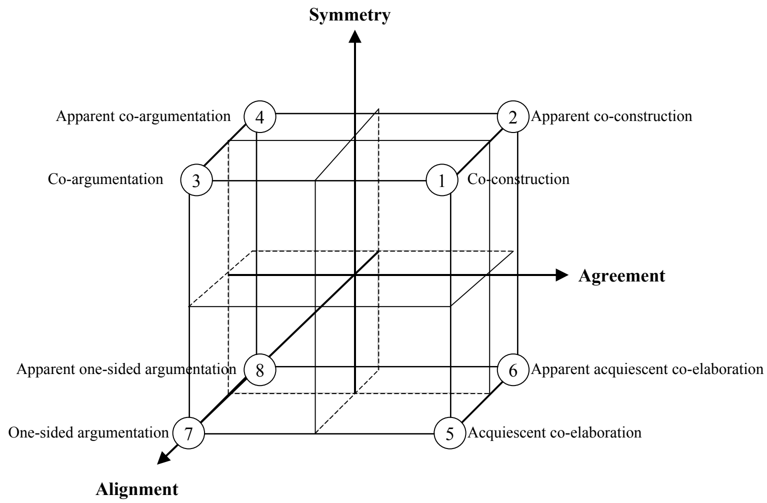


Figure 1. The eight basic forms of cooperation in the cooperative activity of problem resolution, redrawn from Baker (2002).

A study of the literature revealed factors that contribute in diverse ways to collaboration. However, they are not put into relation with a model that describes the forms of collaborative activity through precise dimensions, such as those in Baker's model (see above). This is the objective of our article. We organized the factors we found in the literature into two types: internal and external. Each type of factor contains examples of different granularity. In regards to internal factors, a factor can be internal to the individual or internal to the interaction between individuals.

The factors that are internal to the individual are for example, self-efficacy (Bandura, 1994), adherence to the working principle, altruism or favorable opinion of collaboration as an approach to problem solving (Suangsuwan, Wiratchai, & Wongwanich, 2006). There are also numerous factors internal to the interaction between individuals. For example, the structuring of communication at a distance (Baker & Lund, 1997), the socio-institutional roles of participants (Lund, 2003), the exchanges of a social nature at the beginning of an interaction (van Amelsvoort & Andriessen 2003), and finally the extent to which participants take into account non-verbal body language (Gregori & Brassac, 2001) are all correlated with diverse ways of describing how collaboration occurs.

The external factors of a technological, cultural, organizational, physiological and economical type can also influence the ways actions are carried out in collaborative and distributed communities (Strauss (1993), cited by Fjuk & Dirckinck-Homfeld, 1997). Concerning finer grained external factors, the availability of material resources can influence the way in which collaboration evolves: (Scott, Mandryk & Inkpen, 2002). In addition, the control of a resource (e.g. the manipulation of a video) can be determined by the seat one chooses (Krafft & Dausendschön-Gay, 1999).

The first type of factor (internal) and more specifically, the factors that are internal to the interaction between individuals will retain our attention for the research presented here. In what follows, we apply Baker's model (2002) to two new corpora, gathered in two design situations (a pilot study and a principal experiment), both mediated by computer and at a distance. The dimensions that constitute the forms of cooperative activity (symmetry, accord & alignment) are distinguished according to a methodology adapted to our corpora and from this, we deduce a subset of possible forms of cooperative activity. An analysis of the first corpus identified three factors internal to the interaction between individuals that were correlated with different forms of cooperation in Baker's model. These correlations were tested on the second corpus. In the following sections, we present our methodology, our results and interpretations. Finally, we present our conclusions and our perspectives for this research.

Methodology, analyses and results

In this section we briefly describe our pilot study and show how the results enabled us to form hypotheses about the correlation of specific forms of collaborative activity with three factors internal to interaction between individuals. These hypotheses are tested in the principal study, also described below.

Pilot study

Here, we describe the participants, their prescribed task, the resources they had at their disposal, the experimental protocol, the corpus obtained, the analyses carried out (coding of interactions and determination of forms of cooperative activity), our results and finally our observations and hypotheses.

Participants, task and resources

Six university students, non-experts of origami, but experienced in working on computers, formed the three observed dyads. The participants were asked to compose a procedural text for folding an origami paper hen. They carried out this task on the Internet, each on his or her own computer. The participants did not know each other before the experiment and were asked not to attempt to identify their partner, once they connected. Lack of available computer rooms meant that in reality, participants were all in the same computer room, although they were told they were each connected to a person in another location.

The partners had instructions on paper that they could consult at any time. They also had three tools on their computer screen, two of which are included within DREW (1) (Corbel, Girardot, Jaillot, 2002; Corbel, et. al., 2003). Figure 2 shows:

1. At the top left: a video of the origami folding task that the participants can play at their leisure. The participants could fast forward, rewind or define a particular time stamp in order to get to any part in the video.
2. At the right: a shared text editor (part of DREW) in which the participants composed their procedural text for folding the origami hen. Both partners could write in the text editor, but not simultaneously, due to single cursor. When one person writes, the other sees the text appear in real time.
3. At the bottom left: a chat area with a personal text entry zone (also part of DREW). Pressing the Enter key sends the typewritten text to the shared chat board, thus rendering it visible to ones partner.

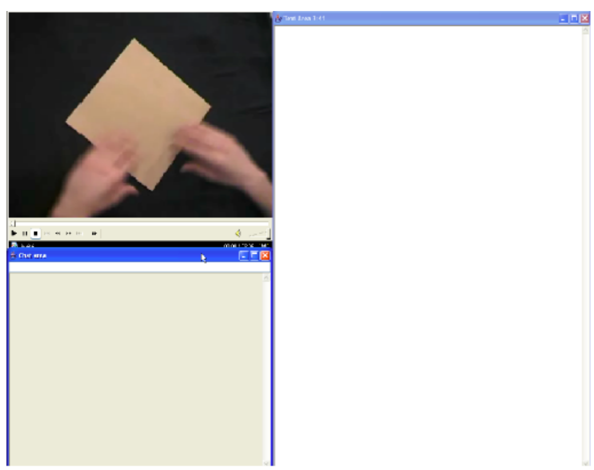


Figure 2. The video and two modules of the platform DREW.

Experimental protocol

The pilot study took place in three stages. First, an experimenter explained the task to the participants and described the tools they could use (5 min). Then, the participants were taken into the computer room. While they carried out the task (1h), 3 experimenters observed their actions in order to characterize their activity and to pinpoint any problems. At the end of the experiment, an experimenter interviewed each dyad in order to gather their impressions and to identify any difficulties linked to the resources or the experimental protocol (10-15 min).

Corpus

The participants' computer-mediated interaction via the DREW platform (chat and text editor) was traced and converted from XML into Excel™ format. The chat messages were saved each time the Enter key was pressed after a message was typed. In regards to the text editor, a first level of granularity saved the totality of the text, approximately every second. This was difficult to analyze (cf. Figure 3). A second level of granularity was thus created (Dyke, 2006). Rather than send the entire contents of the text editor to the server, only the modified line (which was given a number) and its state before the modification were saved (cf. Figure 4). A line of text is sent to the server in three cases: 1) when there is no activity in the text editor for more than 5 seconds (= *production: timeout*), 2) when the participant changes to the chat (= *production: speaker changed module*) or 3) when ones partner starts composing in the text editor at the same time (= *production: speaker was interrupted*).

Time	**Participant**	**Action in the interface**	**Module**
14:27:7	Aldébaran	ok let's start	chat
14:27:13	Bételgeuse	ok, so this should work	chat
14:27:18	Bételgeuse	trial2	textboard
14:27:22	Bételgeuse	In ord	textboard
14:27:23	Bételgeuse	in order	textboard
14:27:24	Bételgeuse	in order to	textboard
14:27:25	Bételgeuse	in order to do	textboard

Figure 3. An extract of the interaction (translated from the French) before modification of the trace

Time	**Participant**	**Action in the interface**	**Module**
14:27:13	Bételgeuse	ok, so this should work	chat
14:27:18	Bételgeuse	**begins writing** 1< trial2 1> in order to do an origami hen you need a piece of paper 2< and now do you see something	textboard
14:27:43	Bételgeuse	*** production: speaker was interrupted	textboard
14:27:44	Aldébaran	**begins writing**	textboard
14:27:44	Aldébaran	*** production: speaker was interrupted	textboard
14:27:44	Bételgeuse	**begins writing**	textboard
14:27:54	Bételgeuse	1< in order to do an origami hen you need a piece of paper 1> in order to do an origami hen you need a piece of paper in a square format*** production: timeout	textboard

Figure 4. An extract of the interaction (translated from the French) after modification of the trace

Analyses: two-dimensional coding method

A two-dimensional coding method was elaborated using the chat interventions of the pilot study as an initial corpus. We first determined the pragmatic orientation of the utterance as primarily focusing on one of four categories: the product (the written instructions for the origami hen), social aspects of discourse, the carrying out of the task and the activity (cf. Table 2 for explanations of categories and examples). We then coded each utterance according to the speech act (cf. Austin, 1962) that was used: proposition, acceptance, refusal, correction, directive, affirmative, question & response (cf. Table 3). This allowed us to determine the cooperation as a function of the utterance's value.

Table 2. Definitions of the possible functions of an utterance and examples translated from the original French.

	Definition	Example
Social	Utterances that have the function of conveying emotions and thoughts of participants, expressions of politeness or any sort of utterance that does not directly concern the task.	"shall we say until our next game?!"
Carrying out the task	The utterances that concern carrying out the task refer to the manner of proceeding, for example the division of roles or procedures or strategies to adopt.	"how do you want to do this, we type here, then in the text area?"
Activity	Utterances concerning "activity" are used in order to discuss what one or one's partner is doing or has done.	"i'm looking at the video"
Product	Utterances that essentially concern the content of the product (instructions for folding the origami hen) as well as the description of the video.	"then unfold again your sheet of paper you should have your initial sheet"

Table 3. Definitions of the speech act categories.

	Definition	Example
Proposition	Propose, launch a debate on a proposition, either implicitly or explicitly.	“the next part : take out the end of the blue corner of the center of the square that is folded in two and mark the fold.”
Acceptance	Show agreement with the utterance of one’s partner.	“yeah, that’s perfect”
Refusal	Show disagreement with the utterance of one’s partner.	“too complicated, don’t get it!”
Correction	Make something precise or modify a previous utterance.	“but I would add the meaning, like: the points that you just folded outwards…something like that”
Question	An utterance that shows a request, a search for understanding or for information, directed at one’s partner.	“how will you start?”
Response	An utterance that gives information in answer to a previous request.	“i’m looking at the video” (response to the above example question)
Affirmation	Give a piece of information.	“well, most of the work is coming up”
Directive	Not give the choice to one’s partner to either refuse or accept the produced utterance. Give an order or obligate one’s partner to carry out an action.	“erase it if you don’t like it and write something in its place”

Determining the form of cooperation

In order to determine the form of cooperation for the different dyads, we used Baker’s model of (2002), validated for pedagogical situations of cooperative problem resolution. As our situation was of another nature — a design task — we had to find a way to apply this model in our own context. We needed to find a way to characterize the three dimensions used to define forms of cooperation. *Symmetry* was defined according to two indicators relating to text writing, the principal task: 1) the comparison of the number of interventions in the “textboard” between the participants tells us whether the text writing is equitable; 2) the chat interventions of each participant concerning the text writing also allows us distinguish the transactional role of “proposer” (i.e. does one partner suggest more text proposals?). *(Non)-alignment* was illustrated by the (presence) absence of phrases of the type “i am lost”. Granted, the absence of such phrases does not *guarantee* alignment: partners could agree to work on different parts of the problem. Also, partners could be aligned, but not have attained a common understanding of their work. The observation grid was also an indicator of alignment: certain partners watched the same part of the video clip at the same time and could thus orient their talk about it. Finally, *agreement* was decided by coding speech acts: the presence of corrections and refusals determined whether or not the dyad was generally in agreement.

Results

Two of the three dyads were in complete opposition. One of them was in “co-construction”: symmetrical (with equal roles), aligned (shared understanding) and in agreement (cf. Figure 5). The other dyad was in “apparent one-sided argumentation”: asymmetrical (different roles for each), non-aligned (e.g. lack of shared comprehension) and in disagreement (presence of corrections or refusal of other’s utterances) (cf. Figure 6).

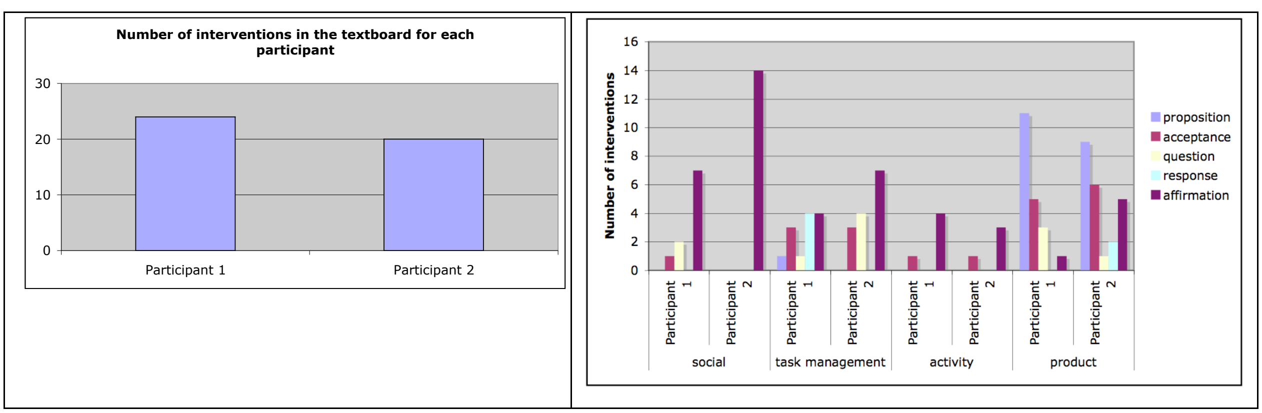


Figure 5. A dyad in co-construction

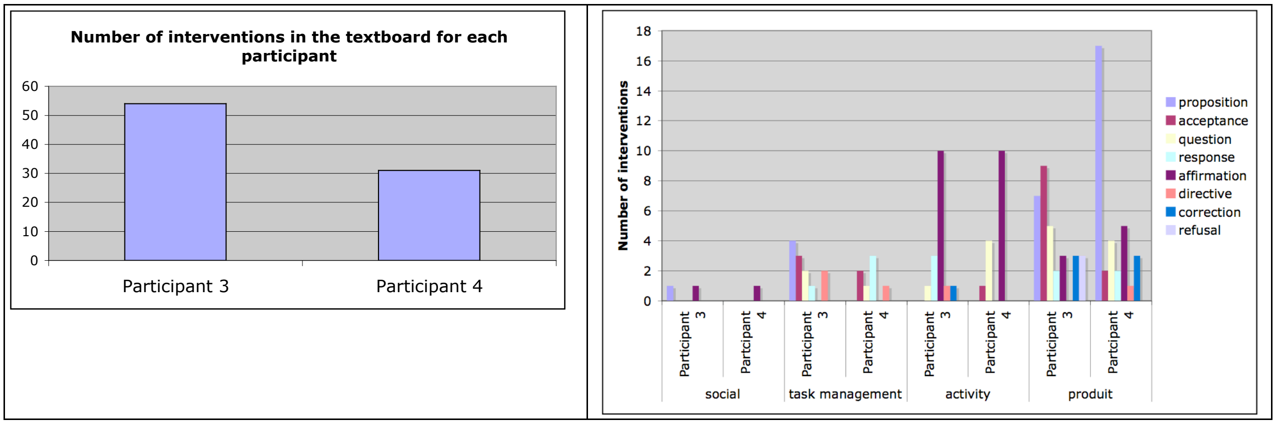


Figure 6. A dyad in apparent one-sided argumentation

Observations and hypotheses

Different observations were made by relating the forms of cooperation used by the dyads and the function of their utterances (cf. Figure 7). We can clearly see that the dyad in co-construction (symmetrical, aligned and in agreement) shows a higher proportion of socially oriented utterances. The correlation of the quantity of socially oriented utterances with good symmetry is thus the first hypothesis we sought to test. In a similar vein, we observe a higher proposition of utterances concerning carrying out the task for the dyad in construction. Our second hypothesis proposes that this type of utterances is also correlated with good symmetry.

The dyad in apparent one-sided argumentation shows a larger quantity of utterances in regards to activity than the other two dyads. This could indicate that the two actors are trying to align themselves by telling each other what they are doing in order that they may synchronize. Our third hypothesis is thus that the quantity of utterances concerning activity will be correlated to a poor alignment.

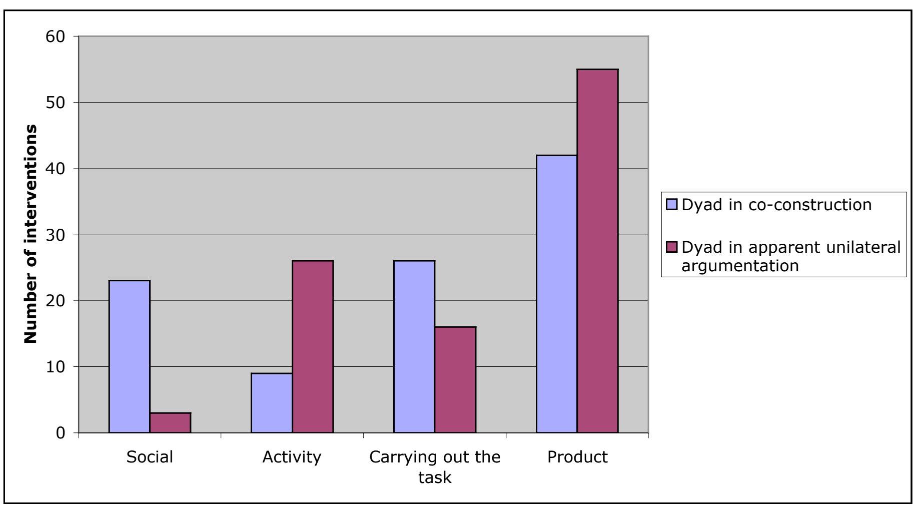


Figure 7. Percentage of utterances by function of utterance and by dyad

Principal experiment

In order to illustrate the differences with the pilot study, we present in the following sections, the participants, the material they used, the task, the experimental protocol, the corpus, the analyses carried out, the results concerning the verification of our hypotheses and finally, our interpretations.

Participants, material, task and experimental protocol

Ten dyads (twenty students aged 20-30 years) participated in the experiment. They were non-experts in origami, regularly used chat and knew how to type on a keyboard.

The material underwent a number of changes from the pilot study. The paper hen was replaced by a paper box, easier to fold in general and with less variation in difficulty. The text editor was also modified in order to allow the two participants to write simultaneously; two cursors instead of one were available. During the pilot study, the presence of one cursor created conflicts that reduced the usage of the text editor to one person at a time. Having two cursors available could favor a more symmetrical cooperation as both partners can write simultaneously (cf. Dyke, 2006). Otherwise, the platform DREW remained identical with the chat and the text editor as well as the video.

Some other modifications were made as a result of problems encountered during the pilot study. After the initial introduction (5min), we added a presentation of the tools and their functions (5min). In addition, a conception micro-task was inserted immediately before the task in order to familiarize the participants with the tools they were to use (10min). The questions were given in questionnaire format in order to avoid influence on the part of the experimenter, but also to obtain information that a participant may not want to divulge in front of his or her partner. (5min). Finally, an individual interview was also conducted (2min).

Corpus, analyses and results

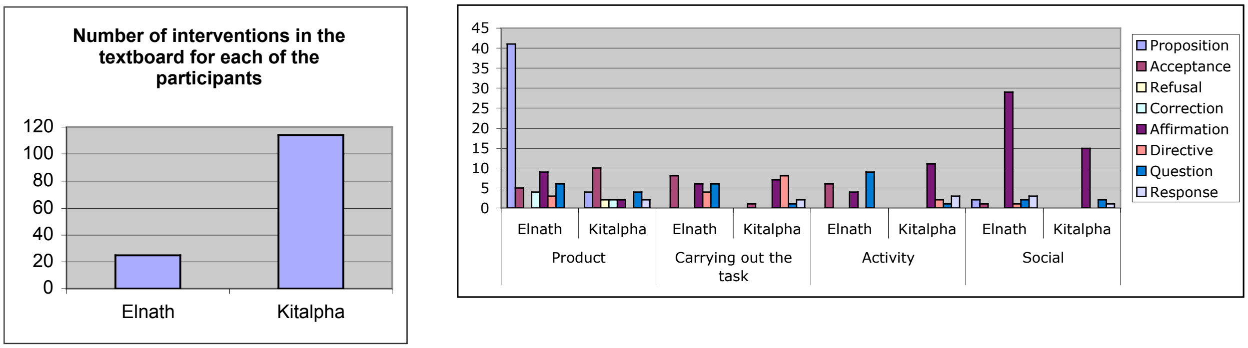
The ten interactions of the ten dyads were automatically recorded by DREW (chat + text editor) and were transformed from XML into Excel™ format (as for the pilot study).

The same coding scheme used in the pilot study was applied to the corpus (on the chat interventions). Then, inter-coder reliability was performed on six of the ten dyadic interactions. Three different coders coded respectively three, two and one of the six interactions, depending on the time they had available. A comparison of these results was done (cf. Table 4) in relation to the original coder, who coded all ten interactions. The average of agreement of the three coders in relation to the original coder was 77.24% for functions and 71,18% for speech acts. As the percentage to be obtained in order for a coding scheme to be reliable is 70%, the coding of both the utterance function and the speech acts is validated (De Wever, Schellens, Valcke & Van Keer, 2006).

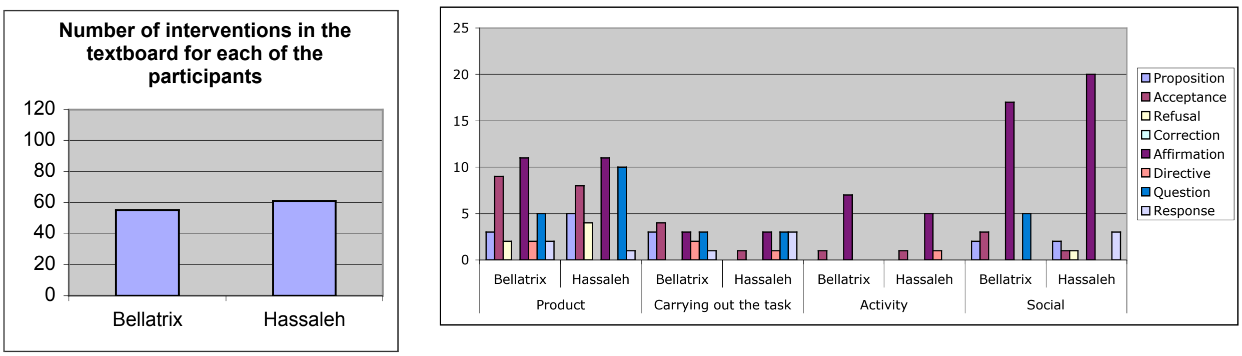
Table 4. Inter-coder reliability; Percentage of agreement with the 1st coder, creator of the coding scheme

	Dyad name	Functions	Speech acts
1st coder	Asterope-Gianfar	75,00	71,71
	Rastaban-Yildun	80,88	75,73
	Pleion-Wezen	84,30	72,25
2nd coder	Deneb-Jabbah	87,06	67,41
	Fornacis-Lesath	70,83	73,61
3rd coder	Sargas-Zibal	65,35	66,34
Average of agreement		77,24	71,18

As for the pilot study, and using the same indicators, we were able to identify many forms of cooperation: three dyads in "apparent co-argumentation" (symmetrical, non-aligned, in disagreement), four dyads in "apparent one-sided argumentation" (asymmetrical, non-aligned, in disagreement), two dyads in "co-argumentation (symmetrical, aligned, in disagreement) and one dyad in "one-sided argumentation" (asymmetrical, aligned, in disagreement). The graphs below show (a)symmetry and (dis)agreement and illustrate two examples of the differences between a symmetrical and a asymmetrical dyad. (cf. Figure 8 and Figure 9).



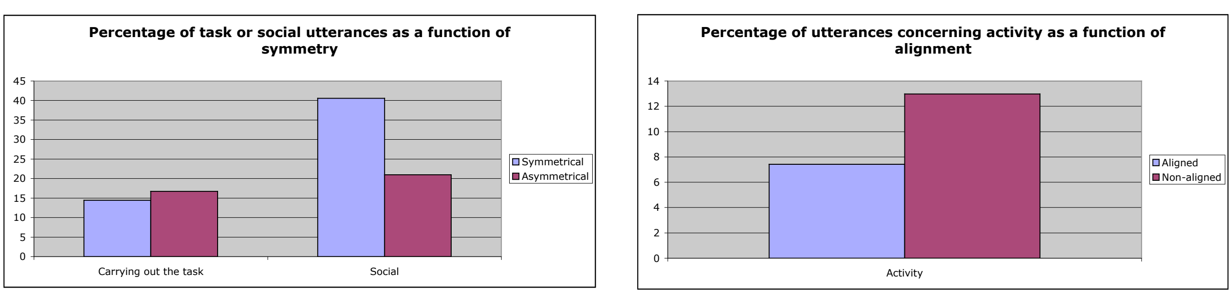
<u>Figure 8.</u> Example of a dyad in apparent one-sided argumentation (asymmetrical)



<u>Figure 9.</u> Example of a dyad in apparent co-argumentation (symmetrical)

Once the forms of cooperation were determined, we calculated 1) the average percentage of the utterances concerning activity according to whether the dyad was aligned or not and 2) the average percentage of the utterances concerning carrying out the task on the one hand and socially oriented utterances on the other according to whether the dyad was symmetrical or not. (cf. Figure 10). In order to ascertain whether the differences between groups were significant, we performed the non-parametric Wilcoxon test, considered to be the equivalent of the t-test.

Firstly, the quantity of socially oriented utterances is twice as large within the interactions of symmetrical dyads than for asymmetrical dyads. The Wilcoxon test shows that this difference is significant and that the two groups are different (Ws=16, p=0.01). Secondly, the quantity of utterances concerning activity is almost twice as large within the interactions of non-aligned dyads than for aligned dyads. The Wilcoxon test shows that this difference is significant and that the two groups are different (Ws=7, p=0.025). Finally, the quantity of utterances concerning carrying out the task did not differ according to dyad symmetry. According to the Wilcoxon test, the two groups are identical (Ws=28, p>0.1).



<u>Figure 10.</u> Cross between utterance function and the value of Baker's (2002) dimensions of cooperative problem solving: alignment and symmetry

Interpretations

Contrary to the data from the pilot study, no dyad was in agreement. We notice much more argumentation on the content of the instructions the students wrote. Perhaps the presence of two cursors in the text editor allowed participants to write what they wanted without first expressing themselves in the chat module and this created disagreement. The presence of one cursor obligates the two participants to reflect together on the content of the instructions before writing them. Viewing a larger number of dyads allowed us to see that being aligned at a distance is rather rare (seven dyads out of ten are not aligned) Not perceiving certain actions of ones partner and not being able to establish eye-contact with him or her does not help in synchronizing reflections and actions.

In regards to the link between (a)symmetry and the quantity of socially oriented utterances (1st hypothesis), it is possible that maintaining good social rapport with ones partner allows for a relation of equality that translates into equitable transactional roles, assuming similar socio-institutional roles. The interactions of symmetrical dyads contain a higher quantity of socially oriented utterances than the interactions of asymmetrical dyads.

However, whatever the form of cooperation, it seems necessary that dyads exchange utterances dealing with carrying out the task. Our 2nd hypothesis is thus not confirmed. There is no link between symmetry and utterances about task. At first glance, this is contrary to the research of Lahti, Seitamaa-Hakkarainen & Hakkarainen, (2001). They have found differences in the proportion of the interaction consecrated to the organization of a design task according to group. Indeed, it seems that groups that "collaborate" discuss in greater length the organization of their design than the groups that "cooperate" or simply "coordinate". Their work environment has more modules that allow for more of a difference in task organization according to group. Certain modules are more pertinent than others in carrying out the task and this leads to choosing amongst them. On the other hand, our own participants only had to organize the use of the textboard and this module is inherent to the writing of the instructions and thus must necessarily be managed.

The link between (non)-alignment and the quantity of utterances concerning activity shows that the lack of information emanating from ones partner concerning his or her activity is compensated for by transmitting this information in writing (chat messages). This was our 3rd hypothesis. When partners are not aligned, it seems they seek to synchronize themselves by expressing what they are doing or by asking what their partner is doing. This is shown by the higher quantity of utterances concerning the activity than partners who are aligned.

Conclusions and perspectives

Our work has enlarged the field of applicability of Baker's model (2002); we have shown it is possible to apply this model with success to computer-mediated interactions whose objective is the design of a procedural text (instructions for origami folding). We have also established a correlation between certain dimensions of this model and three factors internal to dyadic interaction. Firstly, there is a greater quantity of socially oriented utterances in symmetrical interactions than in asymmetrical interactions. Secondly, there is a greater quantity of utterances dealing with activity (e.g. i'm looking at the video) in non-aligned interactions than in aligned interactions. Thirdly, whatever the cooperation type, and considering that all dyads were in disagreement, there is a high quantity of utterances that deal with carrying out the task.

In these two studies (pilot and principal), only the chat messages were analyzed for content. In the near future, we would like to analyze the contributions made to the text editor from two angles: the type of contribution (new production, correction, etc.) and the participant who contributed. This would allow us to refine the notion of symmetry in relation to the whole task. It would also be interesting to relate these observations to the quality of the product in order to appreciate which form of cooperation is optimal.

Endnotes

(1) DREW (*Dialogical Reasoning Educational Webtool*) was designed and developed during the European project SCALE, (Internet-based intelligent tool to Support Collaborative Argumentation-based LEarning in secondary schools, 2001-2004), 5th Framework, IST (Internet Societies Technologies).

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Acknowledgements

We would like to thank Jean-Laurent Cassier, John Bouvery and Magalie Ollagnier-Beldame for their work in carrying out inter-coder reliability.

Web based platforms in co-located practice – The use of a wiki as support for learning and instruction

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Abstract: This study describes how a wiki platform worked as a resource in a university course on applied ethnographic research method. The platform was primarily used for uploading field notes from students' ethnographic work. We describe the use of the wiki in terms of how it supported orientations among students towards relevant competencies involved in fieldwork, and how teachers used it as a way of gaining access to students' work. We discuss these functionalities in relation to ethnomethodological work on learning-and-instruction, showing how wiki entries were used as references in students' and teachers' talk. Distributed activities were thereby made available for instructive practices, and the competencies involved in note taking and observation could be collaboratively oriented to. We thus show that although the wiki was a web based distributed tool, its primary pedagogical functionality lay in its being used as a resource in co-located face-to-face talk.

Introduction

Wikis are simply structured web-sites, based on the idea of unconstrained editing possibilities, enabling anyone to upload and edit material. The most well known example of a wiki is the online encyclopedia Wikipedia, with the English language version collecting over 1.5 million articles. The originators of the wiki idea described this type of system as "a freely expandable collection of interlinked web pages, a hypertext system for storing and modifying information" (Leuf & Cunningham, 2001, p. 14). The idea of the wiki was to create "the simplest online database that could possibly work" (www.wiki.org).

This is a study of how a wiki was used as a resource in a master's level course in applied research method, a course covering the basics of design-oriented fieldwork. The background of the implementation were the hypotheses that this might be a good way for students to manage collaboration in their project work, and that the wiki could prove pedagogically useful through the ways in which it allows students to share their work with peers. In this paper, we focus on these pedagogical aspects. The study places itself in the context of studies of complex interventions in educational settings (see Brown, 1992), looking at the *process* rather than the learning outcomes of the course (see Koschmann, 2001). We will not give an exhaustive account of the "systemic whole" (Brown, 1992) of these processes, however, but rather illustrate and discuss a set of interrelated points about wiki functionalities on a more general level. In our description of the use of the wiki we will articulate an approach that focuses on how the technology supported students and teachers in showing, orienting to, and "making visible" the subject matter of the course (Lindwall & Lymer, 2005; 2005b). In that description, we make use of ethnomethodological understandings of instructive practices (e.g., Goodwin, 1994; 2007).

The central concerns of CSCL were formulated by Koschmann (2002, p. 20) as pertaining to "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". Within CSCL, joint activity and collaboration is recognized as particularly conducive to fostering learning, through the practices of articulation and interaction required to collaborate (Bruffee, 1973; Stahl, 2002). For distributed activities, a collaborative or joint activity becomes harder to achieve (Kreijns, Kirschener & Jochems, 2002). In particular, the objects of collaboration, the concrete *things* around which collaborative learning is organized (Arias, Eden, Fischer, et al., 1999) will not normally be directly shared in a distributed group (Morrison & Dennis, 2005). Some of the central features of collaborative learning are therefore compromised. The fieldwork focused on in this study was one such context, where distribution of activities hindered effective collaboration. As we argue below, the wiki used during the course showed interesting functionalities through which these problems could be addressed.

Wikis and education

Several studies have been made of educational implementations of wikis (see Schwartz, Clark, Cossarin, et al., 2004, for a review). Two wiki symposia have recently (2005 and 2006) been held, where educational uses were one focus. Among the implementations discussed were supports for developing a "community of practice" for teachers (Da Lio, Fraboni & Leo, 2005); adaptations and improvements of the basic wiki architecture for pedagogic purposes (Reinhold, 2006); support for increased teacher guidance to balance students' free explorations of subject matter content with the desired goals of the curriculum (Lund & Smördal, 2006); and wikis as a way of fostering ICT literacy in a group of university students (Bruns & Humphreys, 2005). There seems to be a general consensus that wikis facilitate "collaborative finding, shaping, and sharing of information" (Reinhold, 2006), but just how this is pedagogically useful is largely unspecified. In this study, we elaborate on this issue, attempting to specify what these collaborative aspects mean in practice.

Implementations of wikis outside of educational settings have been dominated by support for on-line communities that rarely meet face-to-face, rather than serve as resources for physically co-located communities (Gaved, Heath & Eisenstadt, 2006). In contrast, several of the educational uses of wikis are lodged within regular co-located practice (e.g. Lund & Smördal, 2006; Brereton, Donovan & Viller, 2003; Da Lio et al., 2005). Similarly, the implementation described in this study was made to support an otherwise physically co-located community of students, and the function of the wiki can, to anticipate the discussion below, be said to hinge on the surrounding face-to-face talk *about* uploaded text, rather than solely on collaborative work via the platform itself.

A study conducted by Brereton (et al., 2003) engages with the use of wikis and other educational interventions in teaching observational skills to engineering students. Although their focus is not on the wiki as such, one pedagogical aspect of the wiki is mentioned: students' postings of finished analyses on the wiki, the authors argue, allowed students to see differences within the class, and reflect and comment on these differences. As described below, something similar happened in the implementation reported on here, although not confined to post-facto reflections on finished projects. Since the participants in this study used the wiki as a support for their ongoing work in the course, it could be employed as a resource for ongoing talk about their distributed activities. Talking about work, or "collective reflection" on work has been shown elsewhere (Argyris & Schön, 1974; Lundin, 2005) to be important aspects of learning, and technologically supporting this type of practices has been suggested as an important area for CSCL research (e. g., Baker & Lund, 1997; Huppertz, Massler & Ploetzner, 2005). We return to this issue when discussing the specific functionalities of the wiki, looking at talk about work from the standpoint of an ethnomethodologically informed understanding of practices of learning and instruction (e.g. Goodwin, 1994; Hindmarsh & Heath, 2000; Lindwall & Lymer, 2005).

Setting and study

This study focuses on describing some aspects of the use of the wiki. This technology, however, was only one of a range of "discourse contexts" (Gruber, Peyton & Bruce, 1995), engaged in by students and teachers: besides using the wiki platform, the students met face-to-face, both casually on the university premises, in arranged meetings, lectures and supervision sessions, and communicated electronically in a host of different ways, including telephone and regular e-mail. As Brown (1992) points out, when changing one aspect of an educational environment, this has perturbations in other parts of the setting: "the role of students and teachers, the type of curriculum, the place of technology and so forth […] are all seen as inputs into the working whole" (p. 143). Accordingly, before the results of the study can be seen in context, we describe this particular setting by way of delineating the subject matter taught, the organization of the curriculum, and the existing technological infrastructures into which the wiki was fitted.

The goal of the course was to introduce students to the practices of design-oriented ethnographic fieldwork, and engage them in scientific writing through a final. Ethnography has been called "invisible work" (Forsythe, 1999), referring to the ways in which common views in research and industry construe its methods as commonsensical and therefore requiring no special competencies besides "what everyone knows". From our experiences with courses in research method, ethnography does indeed seem to involve several areas of disciplinary competence, which become apparent in students' troubles in the field, as well as when writing reports. The ways in which some of these competencies played out in the course, and how the wiki was used in the process, is described below.

Before the fieldwork started, the students were divided into five groups, each group being assigned a project. Group one studied learning support amongst school kids, investigating activity in a local science discovery centre. The second group explored ideas of supporting mobile workshops, studying repair workshops for trucks, planes and buses. Group three investigated the use of paper in a newspaper and a photo bureau. Group four looked at facility management work in an office building, and the final group focused on messenger firms that made daily deliveries by truck and car. The students were expected to engage in two weeks of fieldwork and then three weeks of analysis and writing of a report.

In connection to the fieldwork, supervision sessions were held where students could discuss their experiences with each other and the supervisors, providing one arena for more explicit instruction, making available a skilled perspective on the students' experiences through the supervisors' comments (Macbeth, 2004). Supervision sessions were also held during the writing of the report, in which teachers commented on students' drafts of the reports. The writing phase was thus comparatively easily available to direct instruction; teachers could comment on students' phrasings, choice of excerpts, analytic categories used etc. For the practices involved in the fieldwork as such, however, direct instruction was more difficult. As discussed below, the presence of fieldnotes on the wiki contributed to the students' work becoming more available for teachers' instructive work.

The wiki

The original aim of the wiki (figure 1) was to allow the students to share their fieldnotes within their fieldwork group. We used the open source 'TikiWiki' (http://tikiwiki.org/) software, one of the most popular free Wiki systems available. Tikiwiki has many of the features of more advanced groupware systems such as support for forums, blogs, and even workflow integration. For our purposes, its ability to protect pages of the wiki with passwords allowed us to support the privacy of fieldnotes amongst the class. The students asked their contacts at the field sites for permission to share fieldnotes with advisors and classmates. All groups obtained permission, except one group where the notes were confidential. For all the other groups fieldnotes were left open, editable to teachers, the respective clients, and the whole of the class. The students were given a demo of the wiki in class, and were asked to enter all their typed fieldnotes into the wiki as the fieldwork progressed. In total over 109 fieldnotes and analytic notes were entered into the system (6 per student), distributed over 86 separate pages in the wiki. Below is a picture of the start page of the wiki.

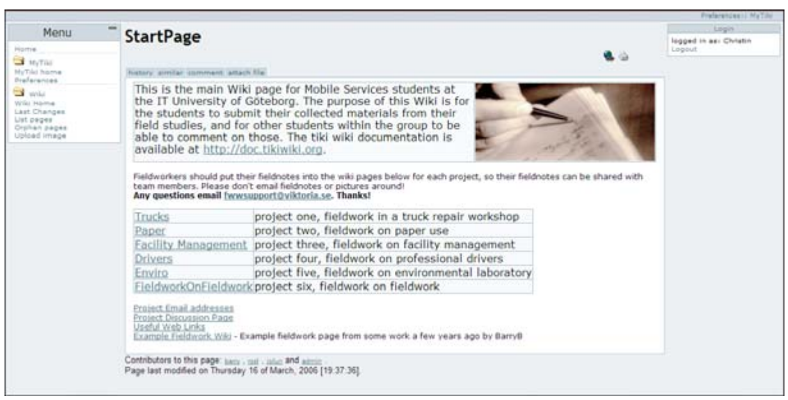


Figure 1: The start page of the wiki used in the course

As seen in Figure 1, the wiki start page consisted in a short introductory text, under which the project sites for each group were listed. The last project, "fieldwork on fieldwork", was our own site, where information concerning this study was made available within our project group and to interested students.

Other available technologies used during the course ranged from paper notebooks to laptops. All students at the program were equipped with laptops that either were their own or rented from the university. The fact that all students had laptops is an important infrastructural aspect of their work in the course. Without personal computers, the wiki would probably not have worked similarly as a resource that was available anywhere for the students, and its educational efficacy could thereby have been compromised.

The study

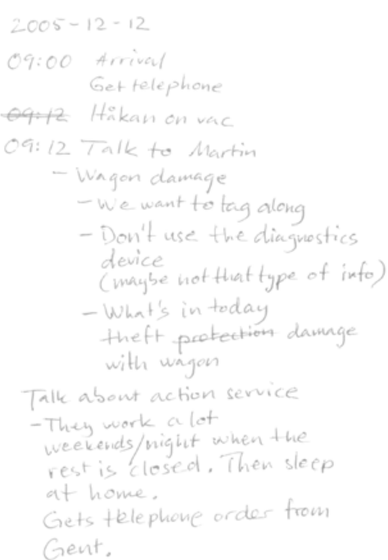
The points made in this paper form part of a larger project studying learning and instruction in IT design education. Our interests range from practices of giving and following instructions in writing, to developing technological support for the students. In order to make sense of the setting, with these different interests in mind, multiple types of data have been collected. First, the second and the third author participated in the course as teachers and supervisors, and could follow the progress of the course first-hand as participant observers. Second, video recordings were made of supervision sessions, as well as of some of the students' own analysis sessions. Third, the use of the wiki amongst the students provided log data on their sharing of fieldnotes. Fourth, interviews were held with students, covering issues such as how they worked with fieldnotes and how they used the wiki. We were furthermore given some of the printed course work reports with the students' and teacher's written notes, and also notebooks from two of the students. Although this material both affords and demands detailed and exhaustive analyses, the following will focus on highlighting and describing a set of interrelated points about the role of the wiki, with excerpts from the data being used as illustrations of this general discussion.

The wiki as a resource for students and teachers

In this section, we describe some ways in which the wiki worked as a resource for students and teachers, restructuring the activities that they engaged in. The presentation takes the form of two sections, each highlighting one aspect of the use of the wiki: first, sharing field notes as supporting student orientations toward relevant competencies; and second, visualizing student activities as support for teachers' instructive work.

Supporting collaborative learning

As thoroughly described by Scribner and Cole (1981), transforming the practices and technologies surrounding writing can also have more general consequences for how participants relate to text, and for the skills and competencies that are engaged with, and learned. Although Scribner and Cole refer to more large-scale differences in literacy practices, a change as local and small scale as the introduction of a wiki – and the associated practices of writing that change along with it – could nevertheless have consequences that go beyond the mere organization of textual work. In this study, one function of the wiki that became apparent was the way in which it supported and encouraged students' orientations towards relevant practices and competencies involved in fieldwork.



09:00	Arrival to Volvo trucks centre
09:02	Picks up the mobile/camera in the car
09:04	Walk to Håkan's room, he is responsible for the Action service department, however, it turns out that he's on vacation, another woman who is a consultant has taken his office. We decide to talk to Tomas about Action Service later, right now he's at a meeting.
09:12	We go to Martin (janitor) we think that he might know of some good truck that we can follow during the day. He says that it's breakfast right now. We ask if he knows of some car that will need a diagnostics device (ex VCADSPro). But since this part of the workshop is mostly responsible for wagon damage and changing stickers (that's why it smells of solvent in the room) they hardly use the diagnostics device. He says that what's there today is a theft damage and a crooked wagon. We decide that this part of the workshop isn't as interesting because of that.
09:16	We continue talking about Action Service, Martin says that they work a lot of weekends and evenings, that is, when the workshop is closed. During the day they sleep at home, they take the "on-call-car" with them, they are on call 24 hours a day. They get their orders through Gent, where Action Service is located.

Figure 2: A comparison between original field note and typed field note.

During fieldwork, one issue that emerged for students was seeing what was relevant in the field. Ethnography's disciplinary competencies became problematic for students in part as to the level of detail at which the "findings" were supposed to appear. This issue surfaced during the early supervision sessions (see section 4.2), but it also became a topic in conversations among peers; the students discussed how to take notes, what to write and how to formulate what they saw in the field. Figure 2 shows an example of an original field note as compared to a note typed on the wiki. It shows how the wiki engaged students early on in the production of text. It was in part through orienting to the skills and norms involved in this basic disciplinary writing that students began developing a sense of there being differently "good" field notes, and thus differently "good" practices of field observation.

As is visible in Figure 2, the typed field note is more extensive than the original, indicating that work has been put on elaborating the note, adding detail, providing explanations of terms etc. Through the ways in which the instructions and the organization of the students' collaborative fieldwork encouraged continuous typing of fieldnotes after each day in the field, the wiki thus influenced the students' analytic work. Entering field notes, however, was not mere typing for private analytic purposes: writing on the wiki was a public activity displaying each individual's activities to the rest of the class and to the teachers. Otherwise private and "invisible" work became accountable work, to which students were made answerable in discussions with peers. The public character of field note typing, and the student's orientation to the field note *as* public, thus led to elaborations of notes with an eye toward the potential reader.

Interestingly, students did not use the wiki much to comment on others' notes. Instead, they reported speaking to one another in person when discussing notes. Face-to-face talk was thus the preferred discourse context in which the proper content and lay out of field notes were highlighted. This *reterritorialization* of web-based media into co-located practice points to an important consideration for CSCL research on wikis and other web-based platforms: collaborative systems with a lot of built in functionalities for distance interaction might not be the best option for the most common forms of educational practice, where distributed and co-located elements of work are intertwined. We return to this issue in the discussion.

During interviews, students reported having read each other's notes, within groups as well as within the rest of the class. This was done "to get an idea of how the other members went about their work, to get ideas on what to focus on", as one student put it. Confirming this, website logs showed students reading each others' fieldnotes, and each note being viewed on average 70 times. As a consequence of this sharing of field notes, practices of wiki use tend to spread. On a surface level, analyses of the wiki pages show the development of common norms for what a "proper" field note was. As one group put up a lot of drawings and pictures, for instance, others could imitate this way of working. Time coding next to field notes (as in figure 2) was one practice that spread quickly. Another illustrative example is the early use by some groups of emoticons (e.g., "smileys") and other textual techniques tied to web-communication; upon being confronted with the more serious tone in other students' fieldnotes, students deleted these icons and imitated the tone of others' notes. These surface traces of collaborative processes suggest that students oriented towards developing and bringing their note taking and typing practices into line, thereby collaboratively defining and orienting towards norms of good practice.

Notes becoming similar also implied observational activities tied to note taking being influenced. The original differences between the group members' notes, that is, did not concern only surface features, but also *what* was captured in the notes. Thus, the disciplined perception (Goodwin, 1994) of fieldwork surfaced as a participant's concern, and the competencies involved in fieldwork were made into topics in students' everyday conversations. Furthermore, through a common orientation towards writing field notes in a "good way", students not only oriented towards doing right, themselves. Such discussions also make possible engaging in practices of explicitly formulating and identifying something done well – to distinguish a good field note as collaboratively defined from a "bad" one. Of course, students could, with some effort, have read each others' field notes and engaged in these practices even without the wiki, but the fact is that during previous years, reading and comparing notes did not become similarly focal for the students, arguably as a result of the extra work taken to make private notes into a publicly available and referable resource.

The way professional competence to a large extent involves a fluency in seeing and talking about the discipline's workaday objects has been a recurring issue in Goodwin's (e.g., 1994; 1995) studies of archaeologists, marine biologists and other professionals. Although Goodwin focuses on vision per se, the instructive practices he describes – what he calls "the interactive organization of apprenticeship" (2007, p. 57) – show how interaction can be pedagogically efficacious by virtue of shared orientations to common "domains of scrutiny". In a similar vein, Hindmarsh and Heath (2000) have analyzed interactions around "objects" as critical to the inculcation of newcomers into the skilled ways of acting in professional settings. In line with these studies, we could see the wiki as supporting the students' initial dealings with ethnography through encouraging orientations towards the visual-and-discursive competencies by which the field is to be seen in terms of relevant categories, organized as a set of "interesting" features and findings, and described through textual practices.

Supporting instruction

The teachers' task during the course was to guide the students and provide timely support in their ongoing work. At the early supervision sessions, the discussions with students centered on their difficulties in deciding what was "important" in the field, as they struggled with getting to grips with what fieldwork was all about. Basically, the students reported either "seeing nothing", or being overwhelmed by the stupendous amount of detail that could be recorded in any setting. "I didn't know what was interesting", was one student's formulation of the issue. In contrast to this, an experienced fieldworker tends to have some bearing on what might be an interesting feature to note, even though every new setting requires a great deal of re-learning. Having read the students' notes on the wiki, teachers were better able to respond to these issues, and could refer to students' field notes in their formulation of instructions. The students' own work could thus be used as "cases" (Macbeth, 2004) in the sequences of talk-in-interaction constituting the supervision session.

To take an example from the group looking at delivery firms: in the supervision session, one of the supervisors brings up an issue that the students have mentioned to him, about the drivers just doing the same things every day, and their fieldwork being "saturated" after two days in the field. Having the students' field notes on the laptop in front of him, he counters their description with one of his own:

Excerpt from supervision session

1	Teacher:	you said earlier that it seems that you are writing the same notes, that you are seeing the same things all the time
2	Student:	yes
3	Teacher:	just before you came in today. ehrm, and eh when I'm looking at your notes they're not, they're kind of specific. so you make kind of good notes. it's not about the same things going on, is it? cause when I look at your notes ((*leans in to look at the screen*)) it's not, "nine forty five, eh ninety two to Marstrand, could you call Kick's at the Arcade". ((*leans back*)) I guess he doesn't make that phone call every day
4	Student:	no but they make phone calls to other customers […] they have the same routine, I don't see the difference, don't know how to interpret

Figure 3: Supervisor (to the left) reading aloud from students' fieldnotes

In this short excerpt, we can see some of the roles played by the wiki field notes in the early supervision sessions. The students' descriptive categorization of "sameness" (turn 1) with regards to their notes and the drivers' work, is juxtaposed with designations of the notes as "quite specific", "kind of good", and "not the same" (turn 3). The conversation continues, with supervisors offering alternative descriptions of the students' own field notes, in order to make them see what a skilled ethnographic vision (cf. Goodwin, 1994) – enacted through the instructions – would see in the notes. The supervisors bring up examples of what they see as "findings" and "interesting things" thereby using the uploaded material on the wiki as resources in their formulations of instructive remarks. Through instructions and corrections, made with reference to the concrete objects present on the wiki, relevant competencies were made visible and thereby pedagogically available for the students (Lindwall & Lymer, 2005). Since this kind of course content involves skills and practices that are hard to articulate and explain in general, having concrete student-produced text at hand proved valuable for the teachers to be able to articulate suitable instructions and advice.

Apart from field notes, the students also uploaded analytic notes from their meetings, displaying for instance how they grouped excerpts from field notes according to their developing sense of what was interesting. This made available to teachers the students' grasp of the discursive practices of social scientific analysis. Recurring ways of reasoning made visible through the wiki – as for example a tendency to make psychological interpretations of *why* people behaved this or that way – could be met during the supervision sessions. Beginning each session with knowledge of students' work proved beneficial, as teachers knew what students were up to even in the absence of any submitted texts. The analytic notes would show, for example, how the facilities management group analyzed their fieldnotes, using the categories "preparations", "communication", and "mobility", while the group studying a science centre used a distinction between "active" and "passive" events, defined respectively as "thinking for yourself, two-sided communication" (such as a visitor asking a guide for directions or seeking information from signs), and "visitor only fed information, one-sided communication" (such as following a guide without asking questions, or "just looking at stuff"). The notes from these two groups thus made visible two quite different analytic venues. The former was more in line with what was preferred, while the latter was responded to as being in conflict with the approaches to interaction and conversation taught in the course. Knowing about these differences was useful for the instructors: they could respond to the students' choices of categories and strategies, seeing them for the ways in which they differently measured up to the sought after brand of design-oriented fieldwork.

This instructive function of the wiki hinges on the *responsive* nature of teaching; teachers and students, that is, "interpret each others' actions and make, what seems to them, relevant responses" (Dyson, 1999, p. 144). Just as students gain access to disciplinary knowledge through the supervisors' instructions, the supervisor gains access to a concrete sequential context in which to formulate instructions through *students'* actions (cf. Lindwall & Lymer, 2005b). And for this, students' actions need to be concretely available in some form. Through wiki entries' presence as "persistent artifacts as discourse reference" (Morrison & Dennis, 2005), providing students' activities with an increased visibility, the teachers' relevant responses could be made with reference to concrete texts, something that otherwise would have had to await the first drafts of the report. Rather than having to instruct students in note taking, observation, and analysis generally, the teacher could respond directly to students' own products, counter students' formulations of their own work, seeing in their notes qualities that they themselves had not the ability yet to see.

Discussion

In this study, we have described and discussed how a wiki was implicated in the processes of teaching-and-learning during a course in applied research method: first, by providing a material support for sharing text, it supported the status of "proper field notes" as an oriented-to feature of the students' work, and as a topic in their everyday conversations. Second, by encouraging a continuous production of text, teachers could assess student activities and use this as resources in their work, partly through the possibility of referring explicitly to wiki notes in supervision sessions.

Students used the uploaded field notes to *talk about* ethnography's disciplinary concerns. Formulating practices as part of getting to know them have been lifted up as an important aspect of learning (e.g. Argyris & Schön, 1974; Nonaka & Takeushi, 1995; Orr, 1996; Lundin, 2005; Höyrup, 2004). This positioning of dialogue among colleagues as a pedagogical practice (Järvinen & Poikela, 2001) shares the CSCL tradition's view of collaboration as particularly conducive to learning (Bruffee, 1973; Stahl, 2002). In this study, we have thought of collaboration in terms of how students and teachers orient towards, show and make visible relevant competencies. We argue that an interest in such orientations might be a useful way of approaching the study of educational technologies; pedagogically relevant aspects of technologies are articulated without treating technologies as independent variables leading to straightforward effects on learning outcomes (see Lindwall and Ivarsson, in press, for a similar approach to the contrasting of two different technologies used in a physics lab).

When describing the use of the wiki, we have not been concerned only with talk, but also with material and embodied aspects of interaction. Having concrete objects at hand to point to and talk about has been seen previously to be an important aspect of practices of learning-and-instruction, in everyday as well as professional settings (cf. Goodwin, 2007); in a study of a tele-services control centre, Hindmarsh and Heath (2000) describe "object focused discussions", a kind of articulation work that the authors argue to be central for the inculcation of newcomers into specialized work settings. Similarly, Goodwin's (1994; 1997) studies of instructive practices in archaeology and chemistry show how deeply the development of disciplinary competence is dependent upon interaction around the concrete objects of the setting. The wiki can thus be said to make the disciplinary objects of ethnography – field notes, analyses, and observations – accessible and referable in students' talk. Thereby, the participants could orient to these objects, and to the competencies involved in their production and proper perception. This was a central part of the role of the wiki, not only in peer-to-peer talk, but also in instruction.

While students used the uploaded field notes to develop a sense of what a field note was, the teacher's task was to provide instructive guidance to the students. The prime site for this was the supervision sessions; in close face-to-face engagement with students, an instructor can provide timely responses to students' actions, seeing in these actions evidence for lack of understanding, faulted presuppositions or the like, and in sequences of verbal remark construe these as in need of correction, thereby showing what was to be taken as a correct, rational and effective way of acting in this setting (cf. Goodwin, 2007; Lindwall & Lymer, 2005b; Lundin & Nuldén, 2007). But this requires of students' actions that they are visible to the instructor, and during fieldwork they typically are not. Through referring to field notes uploaded on the wiki, the instructor could nevertheless talk about students' activities in the field. In so doing, he could instruct them as to what was there to see. Through making available a skilled perspective on their notes, the supervisor could *show* that skill in and as the alternative formulations he offered.

The wiki can be said to have afforded a sort of social translucence (Ericksson & Kellog, 2000; Thomas et al., 2001), in that it allowed students "to observe and imitate others' actions, […] to create, notice, and conform to social conventions" (ibid, p. 873). When systems supporting such visualization of distributed activities have been developed, the context has most often been the implementation of networks of workers or learners that rarely meet in person. Therefore, functionalities for mimicking the structures of ordinary conversation have been addressed in these systems (Ericksson & Kellog, 2000; Kirk & Fraser, 2005; Mühlpfordt & Wessner, 2005). Morrison and Dennis (2005) summarize such efforts within CSCL as having found three aspects particularly important: "visual reinforcement of shared knowledge, persistent artifacts as discourse reference, and shared spaces for mutually editable information" (p. 20). In this study, the wiki was only one of a range of different discourse contexts available to the students. Wiki entries thus worked as *resources in* ordinary face-to-face conversation, rather than as means for *replacement of* the same. In that sense, it was a system for collaboration, rather than a collaborative system in itself. The problems addressed through the use of the wiki, then, were not ones relating to lack of conversational interaction per se, but rather to the relative difficulties involved in establishing concrete shared references in talk, when the activities talked about were engaged in individually, and at different locations. Since this mix of face-to-face and distributed activities is the dominating organization of education, the dominance of collaborative tools for distance interaction might lead to potential applications of CSCL research being neglected.

The functionalities described here should not be taken as specific for ethnography as course content. On the contrary, commenting and criticizing text is a pervasive practice in higher education. Furthermore, many other collaborative activities involve individual work that is similarly rendered inaccessible for others through spatial distribution, hindering a common orientation in talk to competencies involved in that work. Da Lio (2005) makes this observation in relation to a wiki implementation to share teacher practice, stating that "although teachers develop new knowledge through their work, it is often poorly documented and must be better managed to capture both tacit and explicit forms" (p. 86). Likewise, many educational programs involve elements similar to field work. Consider for example the work place practice engaged in by students in many professional study programs (teacher students is one example: see Huppertz et al., 2005, for a study of video-based facilitation of dialogue in a group of pre-service teachers). These similarities suggest wider applications of simple web-based technologies. In particular, we argue that distributed activities, through continuous visualization on wikis or similar systems, might be made more accessible for collaborative co-located practices of learning and instruction.

Conclusion

In this study, two interlinked aspects of the pedagogical usefulness of a wiki have been described and discussed. In particular, the ways in which the wiki could visualize otherwise individual work – and make that work available for collaborative learning and instruction – was highlighted as an important functionality. While many implementations of wikis have been directed at supporting shared databases of student texts *about* some subject matter, this study shows how the use of the wiki can be based not on the uploaded texts themselves, or on interaction through the web based medium, but on face-to-face talk surrounding the texts. Thus, an important value of the wiki lies in the visualization and sharing of work, and the ongoing conversations about work facilitated by that visualization. Distributed groups of learners are not necessarily distributed all of the time, but to the extent that they are, CSCL could offer accessory discourse contexts by which their work is tied together and more easily shared and referred to in instructive talk among students and teachers. The results of this study suggest a set of interesting functionalities of this simple platform, addressing issues concerning peer-to-peer learning, the pedagogical availability of curricular content, and the teachers' task of designing their conduct in relation to the students' developing competencies. Students' reports on how they discussed and developed norms of good practice in ethnography, and brought field notes in line with each other, point to interesting venues of continuing research, providing further details of the actual practices of wiki use. Researching more into these areas would, we argue, be beneficial to developing an understanding within CSCL of the pedagogical potentials of wikis and similar systems.

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Acknowledgements

This research has been financially supported by the Knut & Alice Wallenberg Foundation, Wallenberg Global Learning Network II. It was carried out mainly within the context of the Linnaeus Centre for Research on Learning, Interaction, and Mediated Communication in Contemporary Society (LinCS), and the Network for Analysis of Interaction and Learning (NAIL). Additional support was received from the Kaleidoscope CSCL SIG.

Patterns of Collaboration in Design Courses: Team dynamics affect technology appropriation, artifact creation, and course performance

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Abstract: In a collaborative task, group dynamics have been shown to affect students' grades, motivation to pursue a topic or subject, documentation of the experience, learning, enjoyment of a project, and relationships with their classmates. The results presented in this paper illustrate the effect team dynamics also have upon technology appropriation, by combining proven data-collection strategies and the use of a system that augments paper sketchbooks with multimedia capture and sharing capabilities. We analyze the relationships between students' design notebooks, questionnaires, and interview responses, class observations, and course performance. Our study found that students' use of collaborative tools increases when they believe their teammates to be equally engaged and involved in the project. Moreover, students engaged in successful collaborations are likely to take fewer notes than those involved in conflict-filled collaborations, and students with considerable experience working in groups may bypass critical steps in creating joint problem-solving spaces with each new group.

Introduction:

Team collaboration and innovation in design are emerging as decisive factors in determining and maintaining global competitiveness for firms and countries (Agustine, 2005). Yet design education has been considered "the top drawer of Pandora's box of controversial curriculum matters" (Evans *et al*., 1990), perhaps because of the challenges in establishing hallmarks of good design across situations and contexts. Or perhaps, as a group of engineering design professors suggest, because the collaborative, open-ended, creative nature of design collides often with the convergence required of engineering departments in which it is taught (Dym *et al*., 2005). While some firms have succeeded at instructing recruits in their design process and tenets (*e.g*., Kelley, 2001; 2005), academia seems to lag behind in replicating the success of these small corporations (Dym *et al*., 2005). Recently, however, an interest in evaluations of design education at the collegiate level has begun to percolate (*e.g.* Song *et al*., 2004; Mabogunje, 2003).

Meanwhile, research on collaboration in educational settings traditionally has focused on short-term collaborative episodes and concrete tasks, where there are a limited number of acceptable solutions (*e.g.*, Barron, 2003); and collaboration scripts, where roles are predefined and structured (*e.g.*, O'Donnell, 1999; Dillenbourg *et al*., 2006). Recently, there has been an increased interest towards considering longer-term collaborations (*e.g.,* Goldman *et al*., 2004, Mercier *et al*., 2006). The research we report in this paper is at the confluence of these two developments: we focus on longer-term collaborations where students engage in creative, open-ended projects. Our findings are drawn from analyzing weeks-long collaborative projects in two courses on interaction design: an undergraduate introductory course, and a design studio.

Our evaluation methods similarly combine strategies from collaboration and design research. A significant fraction of the collaboration literature centers on video analysis of students' utterances and gestures, (*e.g.* Barron, 2003; Mabogunje, 2003); others consider the unit of analysis to be the students' use of representations (*e.g.* Yang, 2003; Song *et al*., 2004). Collaborations have traditionally been considered successful according to the groups' performance, measured in terms of grades or number of solutions reached. In contrast, some studies consider what students *themselves* value in collaborative endeavors (Mercier *et al*., 2003; Gillies, 2004; Levesque *et al*., 2001) – which may not correlate with their instructors' assessment. Our analysis for this paper draws insights from class and group *observations*; *interviews* of selected students; as well as pre- and post-experience *questionnaires* measuring attitudinal, self-reported behaviors, and experiences within the groups. We also discuss findings from *quantitative analysis of each student's design notebook*, associated coursework, and performance metrics.

Design notebooks are deeply embedded in the discipline and teaching of design (Verplank & Kim, 1986; Klemmer *et al.*, 2005; Chen *et al.*, 2005). In the design studio course we analyzed, these notebooks typically account for 30% of the students' final grade. Their importance is also reflected in the professional field, where they are considered valid sources for patent disputes. Also known as Idea Logs, the design notebooks provide a space for individual ideation and documentation, reflection, and organization of any project's elements: students take class notes, record team meetings, and sketch, write down, and paste in observations, ideas, and inspiration (typical Idea Logs appear in Figures 1 and 2).

This paper begins by summarizing the implementation framework of the Ideas learning ecology, for which Idea Logs are the starting point, barriers to adoption of such an augmented paper system, and usage and performance metrics. We concentrate on the effects of group dynamics on the appropriation (Pea, 1992; Leontiev, 1981) and usage of the system, as well as the students' enjoyment and performance in the course. Hardware and software can provide incentives and barriers to collaboration, yet our findings indicate that group dynamics may have as powerful an effect — if not more — on both adoption of the collaborative tools and on performance metrics. We find that the type of content and frequency of writing in their Idea Logs, both paper and electronic, correspond with the team's dynamics.

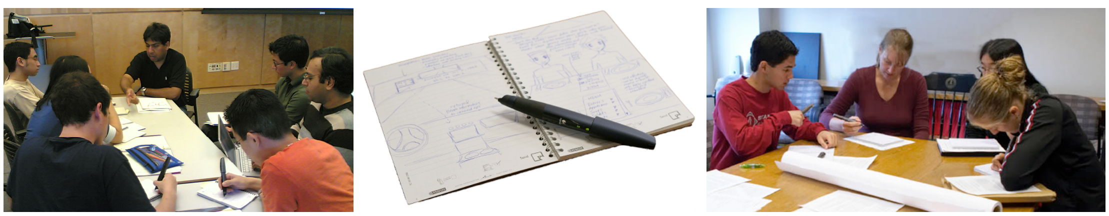


Figure 1. Students during group meetings using the Ideas ecology; the Ideas digital pen and notebook.

The Ideas Learning Ecology:

The quantitative analysis of the students' Idea Logs we discuss was made possible by the introduction of the Ideas ecology, which aims to fluidly bridge the digital and physical world of artifacts used and created by design students. We use the term *ecology* (Barron, 2004) to recognize that students actively engage in learning through a wide variety of social resources, practices, and tools. To capture written content, design students use the Anoto digital pen system (http://www.anoto.com). For the study deployments, we used Nokia SU-1B and Logitech io2 digital pens. When used with an Anoto digital notebook, the pens record time-stamped vector graphics of each stroke the students make, along with the page number. Students may upload and view their digitized notes by synchronizing with a PC. Unlike purely digital systems, the Anoto digital pens also act as normal ballpoint pens: should the pen digitizer fail (*e.g.*, if the pen runs out of battery power), users may continue taking notes and sketching as if they were writing with normal pen and paper. Similarly, the digital version provides a backup should the physical notebook become lost or unavailable. Students can import digital images into Ideas, allowing them to document fieldwork with digital cameras or camera phones, as well as material downloaded from the web.

The Ideas ecology has been in use for over six months, by more than 56 design students, authoring over 4,000 pages of content in the course of their class work. Users interact with captured Ideas content through the ButterflyNet browser (Yeh *et al.*, 2006), which integrates digitally captured paper notes with photographs and other media through a faceted metadata browser (see Figure 2). Notebook pages currently in focus are displayed in the *content panel* on the left; the browser offers the ability to zoom in/out and display multiple pages at a time via a drop-down menu. The *context panel* on the right automatically presents data related to the pages in focus, such as images taken around the time the page was written. At the top of the browser, a *timeline visualization* allows the students to jump to content by date. The height of each bar represents the amount of content written on that date. Flags representing course milestones, indexed by date, provide links to course web pages while simultaneously providing a visual aid for students searching for content related to a given milestone. Exporting notebook pages as images to other programs allows students to complete common tasks such as pasting sketches into documents or sharing their design content through email without the burden of scanning.

The Ideas system supports collaboration among teammates by enabling users to create, join, and leave groups. Members of a group can directly view the notebook pages of other users in the group through the digital browser. Group members can comment on each other's work via highlighting and annotating interesting pages through *tags* (text labels of pages) and *annotations* (text or image labels of page areas). These tags and annotations are indexed and searchable for later retrieval. As the Idea Logs are collected, reviewed, and evaluated several times throughout the quarter, we also added features to facilitate these tasks for the course instructors and teaching assistants, such that they have access to aggregate views of the entire class, as well as the ability to view and annotate any notebook. In addition to supporting design practice, the Ideas ecology is a powerful instrument for studying the practices and behaviors of design students. Digitally augmenting paper lowers the threshold for acquiring aggregate metrics of notebook activity, time-stamped ink strokes enable us as researchers to ask finer-grained questions, and the digital copy allows researchers to examine content without taking the notebooks away from the students at any time.

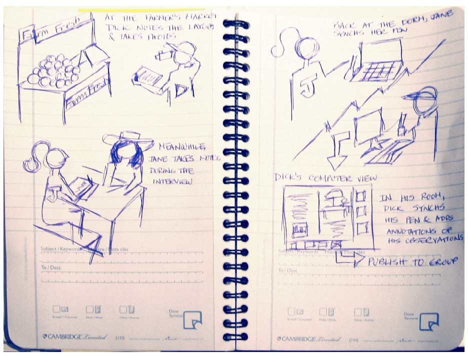


Figure 2. *Left*: Pages 1 and 2 from an Idea Log recoding observations during a Farmer's Market. *Right:* The same pages viewed in the ButterflyNet browser. Notebook pages with their photo and text annotations are presented in the left-hand content panel, while contextual data (*e.g.*, related images, search results) are presented in the right-hand panel. Above, a timeline shows class milestones along with a bar graph visualization of the amount of notes collected on days throughout the quarter.

Study Method:

We review the different methods and evaluations strategies employed, in both the pilot and central study reported, the students' positive evaluation of the technology, and their usage of the Ideas system. In the next section we concentrate on the educational and collaboration findings, and their relationship to the usage metrics.

Technology Probe:

The pilot study ran during the fall quarter of 2005, when we deployed parts of the Ideas ecology to selected sections of the undergraduate introductory HCI design course at our university. Eighteen students used the pens, notebooks and browser, authoring a total of 550 pages over 10 weeks. In the post-experience questionnaire, participants rated the Ideas system as significantly useful, easy to understand, and easy to learn (median 4, 5-point scale). For exporting and sharing design content, students preferred using Ideas to traditional means such as copiers and scanners (median 6, 7-point scale), and commented on the value of the ability to share notebook content quickly and fluidly (exporting the page image to office productivity and email applications), the browser's capacity to display multiple pages, visualize a timeline of when pages were created, and view pages within a calendar.

One of our concerns was the added weight and encumbrance of the pen introduced by the digital capture instrumentation, which could discourage usage. We did not discover an impact of the pen's form factor on content production: the students using Ideas filled an equivalent number of pages to those using traditional pen and paper (40 full pages on average, when accounting for notebook size differences). . Notably, several students used Ideas for classes in addition to the one under study; we hypothesize this is because they found a digital mirror to be useful.

The HCI Design Studio Experience:

Informed by these findings, we conducted a whole-class deployment the subsequent quarter. As with the pilot, we chose this studio course, for its focus on collaborative project work: students' grades are based on their group projects and individual Idea Logs. Moreover, both courses employ the studio critique method for formative assessments.

All 48 students enrolled in the HCI Design Studio course (Klemmer *et al*., 2005) during winter quarter were asked to participate in the evaluation of the Ideas ecology; of these, 38 (10 female, 28 male) agreed. Participating students were provided with the study's consent form, a pre-experience questionnaire, Anoto digital pens, and A5-sized notebooks (approximately 137 mm × 203 mm). At the end of the quarter, students were asked to fill in a post-experience questionnaire and return the filled notebooks and pens. Paper copies of their notes were provided for the students who requested them. An additional eight students chose to participate in the surveys without using the technology. The survey questions were drawn from earlier studies' findings about collaboration, feelings of belonging to a group, interpersonal closeness, friendships among teammates, satisfaction with project outcomes, group interactions and learning, among others (*e.g.*, Hinds *et al*., 2004; Bailenson, 2006; Mercier *et al*., 2003). Questions about technological proficiency, experience with the Ideas tools, and prior workgroup experience or experience in maintaining logbooks—including Idea Logs, blogs, and journals—were also included.

Participants were predominantly engineering students, the majority pursuing degrees in Computer Science and Symbolic Systems, and evenly split between undergraduate and graduate programs. As was the case with the technology probe, no explicit remuneration—whether monetary or in terms of grades—was given to encourage the use of the system, although the Idea Logs themselves were graded for the courses. Students were free to use the technology as much or as little as they desired. The electronic versions of the students' notebooks were not used for grading unless the students requested it.

Results and Discussion:

We evaluate the results of the study by first covering a general overview of the experience and reported barriers to adoption of the Ideas system, the content analysis of the Idea Logs, and the findings on collaboration illuminated through the survey instruments. We then analyze the ways in which the team's interactions moderate usage of the Ideas learning ecology: the type of content and frequency of writing in their Idea Logs, both paper and electronic are impacted by the group's dynamics.

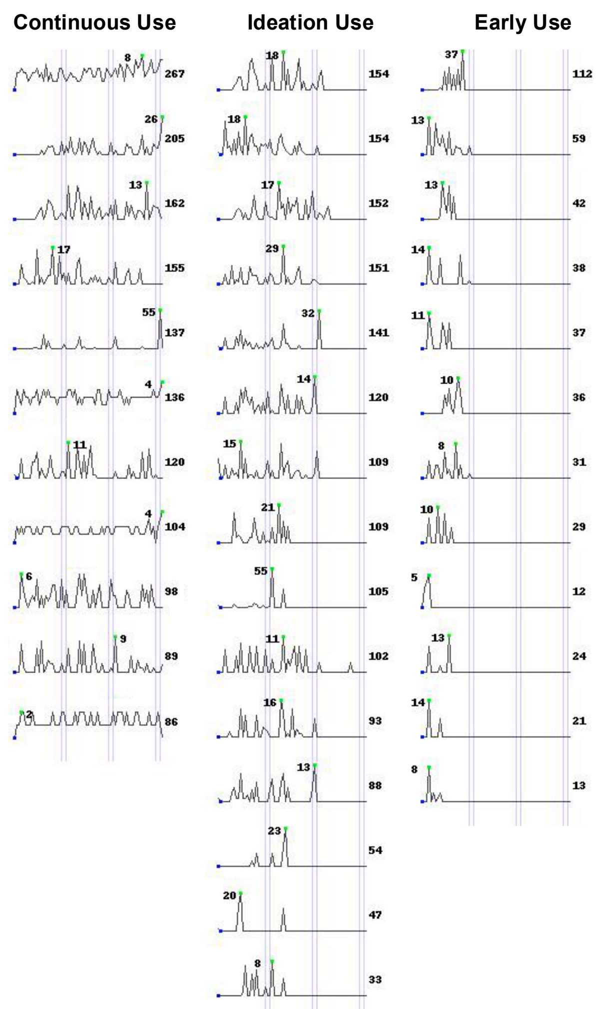
During the 10 weeks of the quarter in the second study, the 38 students using the Ideas system entered 3,637 pages, predominantly working on them during weekdays outside of class. Each student contributed approximately 1.4 pages per day, although students varied greatly in the frequency and amount with which they wrote into their Idea Logs: one student wrote as many as 267 pages (an average of 5.3 pages per day!). Students cited as particularly welcome the automatic digital copy with the additional information of the *timestamp*, as well as the ability to quickly and fluidly insert excerpts from paper notebooks into digital documents. The timeline and the ability to annotate and import related images were also mentioned favorably.

Idea Logs:

We analyzed both the server-logged *timestamp data* for the 38 students who participated in the study and the *content* of the 46 students' Idea Logs (including those that did not use the Ideas system). Idea Logs accounted for 30% in each student's final grade for the HCI Design Studio course; their evaluation by the course instructors and teaching assistant emphasizes the need to ideate and iterate frequently, thus rewarding quantity and scope of ideas. Therefore, it is not surprising to find a large and significant correlation between the students' performance in the class and the quantity of their Idea Log entries (Pearson $r=0.589$, $n=46$, $p<0.01$). Figure 3 shows the appropriation pattern using the server-logged *timestamp* data through sparklines representing the number of pages each of the 38 students filled daily. The trend towards a decrease in note-taking that Figure 3 highlights at the end of the 10-week period may stem from the better fit of notebooks and pens to the ideation and iteration that characterize the early parts of the course, as the last weeks of the quarter are focused on implementation (programming).

Our results indicate a clear need for a digital repository of design content for students; the Ideas system seems to have at least partially addressed that need. Seven of the most frequent and prolific users of Ideas were invited to interview, and they repeatedly mentioned the high value in quickly sharing information among teammates. The perceived value proposition for the students was twofold: the ease of sharing visual ideas; and the lessening of the need to document the same materials as their teammates, particularly during meetings. Earlier we discussed other benefits that students perceived in continued usage of the Ideas ecology; now we address the system's shortcomings that may further account for the differential patterns of usage.

Figure 3. Sparklines showing the number of pages each student completed each day during Study 2, with the values for each student's maximum daily pages, and total number of pages filled throughout the quarter. Note that three groups are easily distinguishable: those that quickly adopted and continued using the technology throughout the quarter (approximately 11 students), those that stopped in the weeks when programming demands took over (10 to 15 students), and those that only gave the technology an early try (approximately 12 students). The paired vertical lines correspond to deadlines for projects and, two days later, for turning in the Idea Logs.



Some of the barriers to adoption of the Ideas ecology are intrinsic to the current incarnations of the technology in the available pen, notebook, and synchronizing interface. The girth of the pen (23mm × 20mm), battery life, and lack of ink color variety were mentioned throughout the interviews and free-form survey responses. It seems likely that future versions of augmented paper technology will overcome these limitations, and in fact new pen models (such as the Magicomm model http://www.originote.com/) seem to be addressing the size and girth concerns. To determine whether the digital pen was primarily responsible for the barriers encountered in these studies, we compared the number of pages written in the notebook to the number of pages synchronized to the computer. Not all pages students wrote were transferred to the browser via synchronization: an average of 186 pages written to 98 synchronized (some were not written with the Anoto pen – perhaps due to its form-factor or qualities, to the students' preference or forgetfulness; others were not recorded, because the pen ran out of battery during note-taking or meetings). The sheer quantity of pages synchronized – almost 4,000 in the three months under consideration – would seem to indicate that most students are able to get beyond the ergonomic shortcomings of the pen. We are interested in exploring this gap further, as the categorization of the content of the notebooks may lead us to determine whether the students preferred the pens for note-taking and related tasks, and a different set of instruments (markers, colored pencils) for tasks requiring greater line control (such as artistic renderings of their interfaces).

Other barriers for our audience are not solvable through off-the-shelf components; for example, the Anoto notebooks also drew a few complaints. Videotaped interviews with students and teaching assistants suggest that lined paper discourages freeform content in favor of textual content. To see if this anecdotal frustration was pervasive, we used the pilot data to compare the number of drawings present in unlined notebooks to those in lined notebooks, finding only a small correlation (Pearson $r=0.153$, $n=79$). As the heft and quality of the paper of the commercially available Anoto notebooks also proved disappointing, we are currently purchasing custom-printed, unlined Anoto sketchbooks with better quality paper.

Analyzing Team Variables and their Interactions:

Analysis of the survey data highlights some characteristics that correlate with these differential usage patters. What other factors influence students' decision to record their thought processes in their Idea Logs? From the survey analysis, we found the number of total pages written in each student's Idea Log to be negatively correlated with the students' reported satisfaction in their current team interactions (Pearson $r = -0.32$, $p < 0.05$). Besides providing an enjoyable working environment, satisfaction with team interactions correlated with the team's project grade ($r = 0.376$, $p < 0.05$). From the perspective of curriculum development, given the equal importance in the final grade measurements of the individual Idea Logs and group project grades, the link between unhappy or conflicted groups and additional contributions to their individual Idea Log raises concerns on the potential causes of such a relationship.

Barron (2003) points out that "research on motivation suggests that the more competitive the environment, the more students focus on finding ways to document and protect their individual competences". It is plausible that fear of not receiving credit for their contributions when working among strangers, or in a competitive environment, motivates students in these teams to document their ideas frequently. This conjecture may also explain, why we found that friendship with teammates negatively correlated with the number of pages each student synched to the Ideas system ($r = -0.326$, $p < 0.05$). From these findings, it would seem that those teams where teammates were satisfied in their interactions and/or were friends before the experience felt less of a need or urgency in recording and documenting their thought process. On the other hand, it may be that friends met more often synchronously, and saw less of a need to share their documents asynchronously. An alternative explanation comes from comprehension theorists, who suggest friends have more "shared semantic fields" and therefore feel less of a need to document these shared perspectives and understandings (Sabelli & Pea, 2004).

The interesting dynamic of working with friends deserves further attention and evaluation. Research has shown that "friends are used to building joint problem-solving spaces and are consequently more familiar with the prior knowledge, communicative strategies, and thinking styles of their partners" (Barron, 2003). Establishing joint problem-solving spaces and creating shared meanings are behaviors that have been shown to be at the center of successful collaborations (Roschelle, 1992). We were particularly interested in evaluating the impact that working with friends had on the students' graphical output, since graphical representations have been linked to the construction of a joint problem-solving space (Brown *et al*., 1989) and making the students' thinking visible (Barron, 2003). Moreover, quantity and type of graphical content in Idea Logs has been shown to correlate with product and process outcome measures (Song *et al*., 2004; Yang, 2003).

We set out to code the graphical output of the students, which proved particularly challenging. We experimented with coding the diagrams and sketches as units, reducing human error by involving four coders working independently. As interpretations of the boundaries between sketches led to inaccuracies, we evolved to considering the quantity of the pages that the diagrams covered as the unit of analysis. Two coders, working independently, analyzed the Idea Logs for their graphical content, counting an average of 62 pages filled with sketches and diagrams during the 66 days of the quarter. The class does not require drawing proficiency, yet some students had as many as 134 pages filled with sketches and diagrams, and no student had fewer than 11 pages devoted to graphical content. This measure, however, is biased towards large size sketches and heavily correlated with the number of pages written by the students. To address this potential imperfection in our measurements, we are developing an "ink counter" for the electronic versions. We hope this tool will compensate for differences in detail and size across students' sketches, although accounting for paper-only sketches will, by necessity, remain challenging and prone to human error.

Using pages filled with graphical content as a measure, we found a negative correlation between prior friendship with teammates and the graphs in students' Idea Logs ($r = -0.30$, $p < 0.05$). Then, given the measuring challenges mentioned above, we calculated the frequency of graphical content as a fraction of all pages written by each group. We contrasted this frequency with a team identity measure, obtained through a seven-point pictorial scale of interpersonal closeness. This scale has been shown in earlier studies to correlate with feelings and behaviors reflecting interconnectedness (Hinds *et al.*, 2004). We validated the scale using six items from Bailenson (2006) on group cohesiveness ("entitativity" items with a Cronbach's alpha of 0.81), and found the two measures to be positively correlated ($r = 0.489$; $p < 0.01$). Individual ratings for interpersonal closeness were averaged across the team, and a large negative correlation emerged once again between the team's interpersonal closeness and the frequency of graphical content aggregated across the team's Idea Logs ($r = -0.581$, $p < 0.01$). These findings seem to indicate that ease of establishing joint problem-solving spaces translates into a decreased dependency on graphical representations to convey meaning and strategies. As working with friends or in a highly interconnected group facilitates the creation of shared meaning, the survey responses suggest that the need for technological and pedagogical support for creating a shared space, such as that fostered by the Ideas ecology, would be stronger in groups where the teammates are not friends at the beginning of the project.

Lastly, as part of the post-experience questionnaire, students were asked to rate on a 5-point Likert scale their agreement or disagreement with 45 statements (divided in five sections) on their feelings about group interactions, group goals, common group challenges, learning outcomes and their satisfaction with the final product design, their learning experience throughout the project, and their collaboration. The number of pages individual students synchronized to the browser correlated negatively with their agreement to the survey question about group members "that did not take the work as seriously as everyone else" ($r = -0.33$, $p < 0.05$). A likely explanation for the disjoint between written and synched pages emerges when we consider that students in unsatisfying collaborations are more likely to individually record and reflect in their Idea Log. Yet these same students may remain reticent to synch and use the Ideas system, because of the potential sharing of their insights with their conflictive teammates. Support for this differential pattern in documenting vs. sharing also appears in the other direction: the total number of pages synched by each group correlates with the project grade ($r = 0.363$, $p < 0.05$) which, as mentioned, correlates with satisfaction with team interactions ($r = 0.376$, $p < 0.05$). Consequently, it would seem that although students in a successful collaboration – or in a team with friends – are likely to take *fewer* notes than those involved in conflict-filled collaborations, students are more likely to *share* and synchronize their notes when they believe that their teammates are equally engaged and involved in the project.

Friendship may not be the only factor influencing students' ability to quickly establish joint problem spaces and create shared meaning; our survey results suggest that this ability may be developed through continued collaborations across teams and courses. Colbeck's interviews of college students (2000) suggested that interdependence (Johnson *et al.*, 1998) seemed to develop more in project teams that included students with prior group experiences than in teams whose members had little or no prior group experiences. We had expected the differences in usage patterns to be related to expertise and prior experience with regularly documenting and recording thought processes. However, our analysis showed a relationship to the students' prior experience with groupwork in related activities ("Outside of this class, how often have you participated in technology-based or design group projects, whether for courses or as part of your job (group projects involve 3 to 5 persons working together)?"), rather than to their prior experience in maintaining notebooks, journals or blogs ("Outside of this class, have you ever kept a journal or diary, whether private or public? Please include blogging experience in answering this question.").

Students' answers to the frequency with which they have worked in technology-based or design group projects were negatively correlated to both the number of graphs in students' Idea Logs as well as the number of pages synched with the system (respectively $r = -0.317$, $p < 0.05$; and $r = -0.576$, $p < 0.01$). It would seem that expertise in the domain and with group interactions could have as large an effect as that of prior friendships among teammates on a group's ability to quickly create shared meaning. Colbeck *et al.*, (2000) found that prior experience with collaborative teamwork both in and outside school contributed to the degree of positive interdependence developed within teams. We would have expected this interdependence to manifest itself in performance gains, yet this high frequency of prior experience in group projects may be misleading, as the same questionnaire item was negatively correlated with the group's grade in the project itself ($r = -0.304$, medium strength non-significant correlation), unlike prior friendship with teammates. We can speculate that familiarity with groupwork practices could lead students to underestimate the need for crafting a shared problem space with every new project. Further research is needed to clarify this complex relationship between prior experience with collaborations and success at a new collaborative project.

We should discuss the suitability of using performance metrics in a design course, where objective evaluations of projects tend to be difficult to validate, as the appropriateness of the design may be best appreciated by the audience for which the product is intended. The HCI Studio course we followed resolves this challenge by inviting a panel of expert judges (instructors of design courses in related disciplines and professionals, among others) to the final project presentations, and adding their evaluation to that of the course's staff. Yet the question remained as to whether the team's perception of a successful project would match the views and criteria of the course staff and expert judges. Several studies have suggested that grades may not accurately represent a successful collaboration (Song *et al*., 2004) and raised concerns that performance metrics may be out of place, both in collaboration studies and courses based on collaboration. Students in our study filled-in the post-experience questionnaire after their final project presentations and demonstrations, after hearing the experts' verbal feedback on their project, and before receiving their project's grade. Yet students' belief that their project turned out well correlates highly with their project grade ($r = 0.404$, $p < 0.01$) and their satisfaction with the project ($r = 0.531$, $p < 0.01$). Similarly, students' satisfaction with their team interactions also correlated highly with the students' reported satisfaction with the final product ($r = 0.636$, $p < 0.01$) and as mentioned earlier, with their project grades ($r = 0.376$, $p < 0.05$). We can therefore conclude that the students' perception of quality accurately reflects that of the judging panel and course staff, and that performance metrics are acceptable dimensions of evaluation for this course. Moreover, it is clear that a successful collaboration and a successful product were intricately linked for this course, even if the multicollinearity between these constructs prevents us from establishing statistical regressions. The approach of evaluating projects through peer, expert and course staff comments seems to both encode an objective assessment, and reflect the students' own criteria.

Conclusion and Future Directions:

In this paper, we described the Ideas learning ecology, and its appropriation during both a ten-week technology probe, and during the HCI design studio course. We analyzed students' design notebooks, class observations, questionnaire and interview responses, then discussed how collaboration patterns affect technology appropriation, artifact creation and sharing, and course performance. We found that students' use of collaborative tools increases when they believe their teammates to be equally engaged and involved in the project. Students in a successful collaboration – or in a team with friends – are likely to take fewer notes than those involved in conflict-filled collaborations, and students with considerable experience working in groups may bypass critical steps in creating joint-problem solving spaces with each new group. Further research would be needed to explore the relationship between groupwork experience and documentation strategies.

Analysis of the content of these students' Idea Logs beyond the scope of this paper continues in three directions: we are interested in replicating the findings regarding graphical content type that other researchers in the area of engineering education have found (Song *et al*., 2004; Yang, 2003), and extending these existing graphical content taxonomies to categorize textual content. Simultaneously, we are evaluating strategies to analyze and make visible the apprenticeship process (Lave & Wenger, 1991) by which students go from novices to expert designers through the lens of their Idea Logs and their progress through the college level curriculum, following the practices of Scribner (1986) and Pea (1993). We are also looking forward to developing (and testing) effective interaction strategies for taking formative assessments of evolving patterns of use of the Idea Logs, and for guiding students towards those patterns of most productive use: perhaps there are forms of collaborative scripts (O'Donnell, 1999; Dillenbourg *et al*., 2006) that may yield replicable improvements to team processes and outcomes in design settings.

From an application development perspective, we are designing several innovations for the Ideas system, including incorporating some of the students' existing digital practices and requests. One of these efforts is leading us to take advantage of the ease and fluidity of online photo sharing applications such as Flickr (http://www.flickr.com). We are also moving towards an implementation that would incorporate display and capture of information on digital whiteboards, as well as the design of group notebooks. Group notebooks are of particular relevance as they seek to provide an intermediate step for students to highlight content for sharing asynchronously before, or synchronously during meetings. Integrating physical and digital tools also opens up new avenues for knowledge building and reflective activities (Scardamalia, 2002). In addition to providing persistent common ground for groups in the midst of projects, we seek to create an ecology of augmented tools that facilitates the creation of status updates, project reports, and electronic portfolios by highlighting vital content gathered over the course of a project. Such an ecology can provide the ability both to *capture* design activity more effectively using physical tools and to better *organize* and *share* design content using digital tools.

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Acknowledgements:

For his assistance with the ButterflyNet browser, we thank Ron Yeh. For their patience and assistance throughout the quarter, we thank the teaching staff of CS147 and CS247: Bill Verplank, Terry Winograd, Björn Hartmann, Doantam Phan, and Dan Maynes-Aminzade. For their insightful suggestions and discussions, we thank Lars Erik Holmquist, Terry Winograd, Antoine Picard, and Emma Mercier. We are also appreciative of our undergraduate research assistants, Isabelle Kim and Paz Hilfinger-Pardo. We are grateful for the support of Nokia and the Wallenberg Global Learning Network, and thank the study participants for their forbearance and cooperation.

Catalysts to creating representational tools and the benefits for learning

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Abstract: Thirty-two undergraduates and six graduate students participated in a medical diagnosis task. They received a set of reference cases and diagnosed new patient cases by ordering and considering the results of medical tests. Half of the participants faced a memory burden as they worked on an initial set of ten new patient diagnoses. Participants then taught a confederate how to perform diagnoses. Finally, two new diseases were introduced, and participants diagnosed five new patients. Participants were allowed to take notes throughout the study. Both the memory burden and the teaching demand led participants to create external representations. Representations used for initial diagnosis, but not for teaching, carried over into the final diagnosis set. Results show that creating a representation was initially inefficient, but led to better performance and learning when participants were asked to adapt to new diseases. Also, a much greater proportion of graduate students than undergraduates created representations.

Introduction

Kirsh (1996) notes that "introducing a tool is one of the easiest ways to change an agent's action repertoire, for now it is possible to do things previously unattainable, or unattainable in a single step" (p. 438). Because the introduction of a tool fundamentally alters the possibilities for action within a problem space, it is an important external adaptation that changes one's own possibilities for action, thought, and communication. This study examines the creation and use of one important class of tools: representational tools, such as trees, diagrams, and tables. Representational tools are important in the work of many disciplines, and they are important in education as well. We are interested in the factors that motivate people to make representational tools and in the effects these tools have on learning and problem solving. Our study is designed around a medical diagnosis task that allows participants to succeed with or without the use of a representational tool. We focus on two research questions:

1. What factors influence whether or not people create a representational tool?
2. What are the effects of participant created representational tools on problem solving and preparation for future learning?

We predicted participants would be more likely to create a representational tool if 1) they could not rely on the situation to support their "unaided" cognition, and/or 2) they had to teach a confederate to complete the task. We also predicted that creating a representational tool might initially impair performance, but would prepare people to learn more quickly when given modified problems.

Design and Procedure

Thirty-two undergraduate students with no medical training participated in a medical diagnosis task. Participants received a set of twelve reference cases. Each case resembled a simple medical chart, with medical tests and associated results. The participants' task was to use the reference cases to diagnose new patients with one of the six diseases represented in the reference cases. For each patient, participants could order a variety of medical tests. They were told to minimize the number of tests ordered for each patient. Blank paper was available for note taking at all times.

Participants were randomly assigned to one of two conditions: the *continuous access* condition or the *intermittent access* condition. In Part 1, *Original Case Set*, participants solved 10 cases or worked for up to 30 minutes. Those in the intermittent access condition were told that they could look at the reference cases as much as they wanted to between diagnoses, but they had to place the reference cases face down while performing a diagnosis. Those in the continuous access condition were allowed unrestricted access to the reference cases. Otherwise, the conditions were identical. In Part 2, *Teaching*, participants taught a confederate how to perform diagnoses. In Part 3, *Novel Case Set*, two new diseases were introduced, for a total of eight diseases, and participants diagnosed five new cases. The new cases included both old and new diseases. Importantly, for the Novel Case Set both conditions had continuous access to the reference cases, so it is possible to see if the earlier manipulation would have a lasting effect even when the condition differences were removed.

Data sources included the order in which tests were requested, the final diagnosis, the time spent on each diagnosis, and any representations that were created by the participants. Data on the order in which tests were requested was further coded to determine the optimality of their search..

Results and Discussion

Across the conditions, participants created a variety of representations including ordered lists and decision trees. Representations were coded into three categories: If-Then, when representations included if-then rules; Simple List, when representations did not include if-then rules; and No Tool, when no notes were made. The contrast between conditions had an effect on the frequency of representational tool creation or modification (see Table 1).

Table 1: Creation and Modification of Representations by Condition

		Part of the Experiment		
Condition	Representation	Original Case Set	Teaching	Novel Case Set
Continuous Access	No Tool	13	6	13
	Simple List	2	0	2
	If-Then	1	10	1
Intermittent Access	No Tool	2	5	4
	Simple List	12	4	7
	If-Then	2	7	5

Notably, participants in the intermittent access condition were more likely than those in the continuous access condition to create or modify a representational tool in Part 3, Novel Cases, even though both conditions had identical instructions and identical access to resources during this part of the experiment. Those who created tools for the Original Case Set tended to modify them for Novel Cases, and those who did not create tools for the Original Case Set did not create them for Novel Cases. Teaching a confederate led many participants to create a representation. However, for those participants in the continuous access condition, creating tools for teaching did not lead to tool use or creation for the following Novel Case Set. It appears that tools for teaching do not necessarily translate into tools for doing.

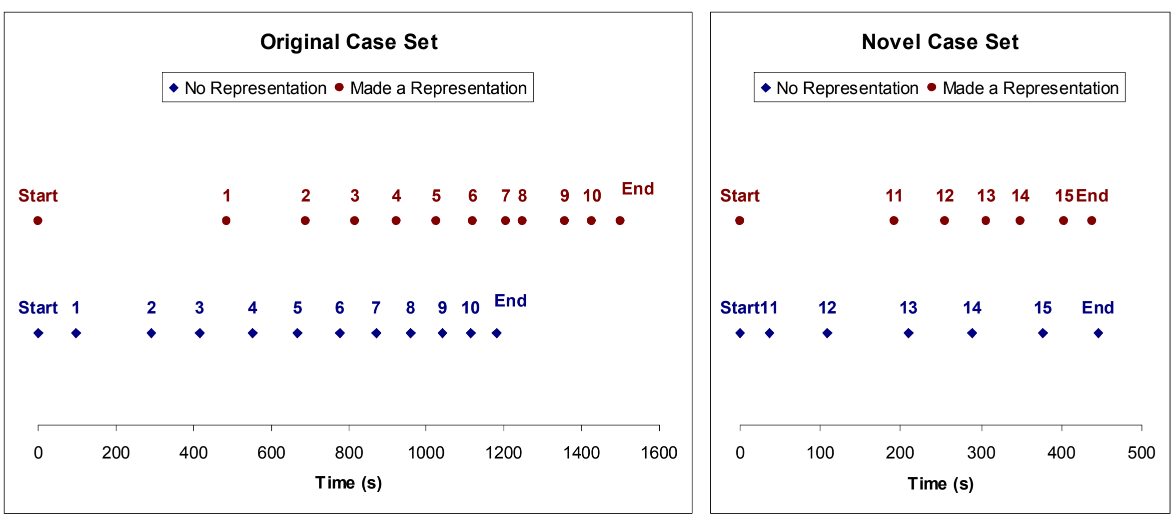

Figure 1. Time Course and Creation of Representations

Problem solving speed gives a rough indication of the implementation cost of creating a tool. Figure 1 shows when participants who did and did not create representations began each diagnosis problem. Participants who created representations for the Original Case Set were slower to begin the task, and finished later than those who did not create representations. However the inefficiency of creating a representation was only temporary. Those who created a representation for the Novel Case Set again began working on the first problem later, but they finished at approximately the same time as those who did not create representations. That is, despite the initial time cost of creating representational tools, participants who created representations caught up by the end of the experiment.

By design, there was little variation in accuracy across participants, but there were variations in the optimality of participants' diagnoses. Each diagnosis was scored with a weighted optimality ratio: a measure of how close the diagnosis came to a perfectly optimal choice and ordering of medical tests, with a maximal score of 1.0. The contrast between conditions was not strongly associated with differences on this measure. However, creation of a representational tool did predict performance. Figure 2 shows participants' performance over time, with participants grouped by the most structured type of tool that they used for diagnoses. The optimality of performance was mediated by the presence of a representational tool: those with If-Then tools outperformed those with No Tool or a Simple List.

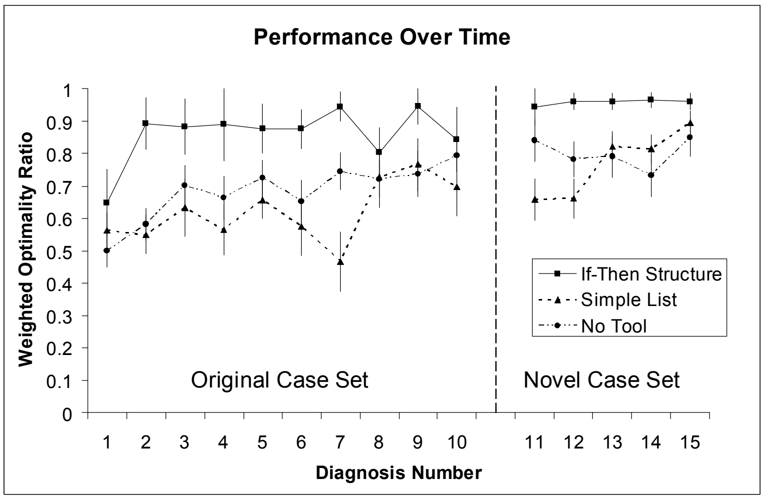

Figure 2. Task Performance by Type of Tool

Finally, data from a sample of six graduate students provides an interesting point of contrast. While only 19% of undergraduates in the continuous access condition created a representation for the Original Case Set, 100% of graduate students in the same condition did so. Although the underlying cause of this difference cannot be directly inferred from the data, the result suggests that graduate students may have developed an adaptive form of representational expertise for dealing with complex information management tasks such as this one.

Conclusion

These results suggest the power of representational tools, not only for efficient problem solving, but also for adapting to new problem demands. The experimental contrast influenced problem solving and preparation for future learning, as mediated by the representational tools that participants created. Surprisingly, tools for teaching did not necessary translate into tools for doing. Experiences creating and using representational tools increased the chances of doing so again in the future, both within the context of the experiment, and, we presume, over longer timescales, as shown by the contrast between undergraduates and graduate students.

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Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant SLC-0354453. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The Effects of Conversations with Regulars and Administrators on the Participation of New Users in a Virtual Learning Community

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Abstract: We analyze new users' participation rates on MOOSE Crossing, a collaborative educational environment. New MOOSE Crossing users who conversed with regulars or administrators soon after joining are found to exhibit more social activity and stay involved with MOOSE Crossing longer than new users who did not. We find regulars to be better at eliciting participation than administrators, but also note a synergistic interaction between the groups.

MOOSE Crossing

MOOSE Crossing is a text-based, multi-user, educational online environment (MUD) for children (Bruckman, 1997). The environment and its kid-friendly programming language, MOOSE, were developed to provide a space where children could learn to program and practice creating writing in a social environment. A range of activities is available to MOOSE Crossing users, including exploring different in-world areas, communicating with others, and interacting with in-world objects and places.

MOOSE Crossing came online in 1995 and has been active for over 10 years. Over this time it has attracted over 1000 users. Its target demographic is children between the ages of eight and thirteen, but it has also attracted younger children, older teenagers, and adults. Its younger users come from a broad range of backgrounds – home-schooled children, groups of children in traditional classroom settings, and children enrolled in after-school programs. Project developers and others involved in creating and maintaining MOOSE Crossing also play an active role in its community. These system administrators are often logged in, and work to keep order, welcome new users, and provide help on using and exploring the environment.

Most young users of MOOSE Crossing are self-motivated, and come and go as they please. Among these users, there is a highly skewed distribution of participation and achievement (Bruckman, Edwards, Elliott & Jensen, 2000). A few strongly motivated individuals spend a great deal of time logged in – creating objects, exploring, and interacting with others. Most users, however, are low- or medium-frequency users – logging in only a small number of days and programming few, if any, in-world objects.

Participation in MOOSE Crossing

Our analysis of participation on MOOSE Crossing comes from the availability of approximately 3.7 GB of logs recorded by the system over the period of time between October 1995 and December 2003. During this time, 1204 users logged in to MOOSE Crossing, including kids, system administrators, and other adults. Of these, 856 were minors under the age of eighteen (most distributed between the ages of eight and thirteen). Everything that happens on MOOSE Crossing is logged, with written consent from parents and assent from kids.

For each MOOSE Crossing user, we compiled a list of statistics: the total number of days the user had logged into the service, the total number of communication commands the user had used, and a chronologically ordered list of every conversational partner the user had. As we compiled metrics of participation for MOOSE Crossing users, we looked for its "regulars" – highly active, social kids who were well-known to the other players, and to the administrators (c.f. Oldenburg, 1999). We picked the ten users with the highest numbers of days logging in to be our regulars. These users were also some of the top socializers, as measured by numbers of conversational partners they had and total numbers of communication commands they entered. Each of the users on this list was also recognized as an important participant by one of the study's co-authors, a long-time MOOSE Crossing administrator. Table 1 shows a comparison of the activity levels of different users we consider in this paper. Since the distribution of the data is highly skewed, we find that the mean and median together provide a better description of the data than either alone. We take our two metrics of participation – the number of communication commands entered, and the total number of days logging into MOOSE Crossing – to be valid proxies for the measure of a user's overall participation. While there certainly isn't a direct, formulaic relationship between our proxy metrics and some measure of "learning," we do suggest that an increase in one or both metrics is desirable.

Table 1: Activity summary for different MOOSE Crossing users.

Group	**N**	**Communication Commands**				**Number of Days Logging In**			
		Median	Mean (St Dev)	Min	Max	Median	Mean (St Dev)	Min	Max
Regulars	10	19653	24583 (19175)	8870	71322	555	670 (245)	397	1154
Other kids	846	20	377 (1327)	0	19724	4	22 (49)	1	393
Administrators	34	214	1816 (3822)	23	16641	130	194 (206)	1	994

Effects of Conversations on the Participation Metrics of New Users

We now examine the relationship between the first few conversations new MOOSE Crossing users participated in, and their eventual level of participation. In particular, we look at the make-up of new users' first few conversational partners, and how it correlates with the metrics of participation we gathered. Are users who initially encounter MOOSE Crossing regulars likely to have greater levels of participation, and if so, in what way? Were administrators, most of whom had the explicit goal of helping and encouraging new users, successful?

In our first set of analysis, we considered only the first three conversational partners of new users. We located the first time each non-regular MOOSE Crossing users were seen on the system, and recorded the first three users they conversed with. In total, 505 MOOSE Crossing users had at least three conversational partners, and we divided these into four groups: those whose first three conversational partners included at least one regular and at least one administrator (group RA, N=31); those whose first three conversational partners included at least one administrator but no regulars (group A, N=86); those whose first three conversational partners included at least one regular but no administrators (group R, N=113); and those whose first three conversational partners included neither regulars nor administrators (group X, N=275). A breakdown of these groups' activity metrics is given in Table 2.

Table 2: Activity metrics for kids with at least three conversational partners.

Group Name	**N**	**Communication Commands**		**Number of Days Logging In**	
		Median	Mean (St Dev)	Median	Mean (St Dev)
X	275	41	446 (1611)	6	26 (53)
A	86	58	824 (1675)	10	39 (54)
R	113	138	733 (1560)	21	47 (70)
RA	31	305	1312 (2296)	18	46 (75)

Trends in Table 2 suggest that talking to either administrators or regulars soon after joining MOOSE Crossing is linked with an increase in participation, both in terms of sociability and the length of time eventually spent on the system. Talking to at least one regular seems to bring about a significant increase in these metrics – the means and medians of both metrics for groups R and RA are much higher than that of group A. Applying an ANOVA and Tukey's HSD post-hoc analysis showed that members of groups A, R, and RA used significantly more communication commands and logged in for significantly more days than members of group X ($p < 0.05$). Also, members of group RA used a significantly more communication commands than members of group A ($p < 0.05$).

To further investigate these effects, we split up new users based on the exact numbers of administrators and regulars they talked to. For this analysis, we considered all users who had at least five conversational partners. There were 457 users who fit this criterion, and we divided them into groups based on how many administrators and regulars there were in their first five conversational partners.

We found that, compared to users who talked to neither administrators nor regulars, users who talked to any number of regulars, but no administrators, had increased participation as measured by both communication commands entered and the number of days logging into the system ($p < 0.05$); the more regulars a new user talked to, the greater the increase. Talking only to administrators also increased participation over talking to neither regulars nor administrators ($p < 0.05$), but to a lesser extent than talking only to regulars. Here, too, more seems to be better, as users who talked to two administrators performed better than those who talked to only one. Those users who talked to *both* administrators and regulars, however, consistently perform as well as or better than the users who talked to only regulars or only administrators.

Discussion

Invariably, new MOOSE Crossing users who interacted with highly active, social MOOSE Crossing residents – its regulars – were likely to show higher levels of participation, both in terms of the amount of communicating they did, and in terms of how many days they logged into the environment. The trends also suggest that talking to a greater number of regulars elicited more participation – the means and medians for both of our metrics of participation consistently increase as users talk to more regulars. Regulars are especially good at eliciting social participation from the users they meet – the medians for all groups where a user talked to at least one regular are high, suggesting that most of the kids in these groups engaged in long chat sessions. We note from experience that regulars are often excited to talk to other MOOSE Crossing users, and other users (especially new users) come to them for help with various aspects of the system. Often, this friendliness also results in the new users spending more time logging into MOOSE Crossing to play and socialize with her new friend(s) – in all groups whose users talked to regulars, when the mean and median of the number of communication commands are high, the mean and median number of days logged into MOOSE Crossing is correspondingly high.

Talking to administrators is also beneficial – most trends in the data point to this conclusion. On their own, however, administrators don't seem to be as good elicitors of participation, especially of social participation (measured by number of communication commands), as regulars. Administrators aren't as likely to immediately try to friend new MOOSE Crossing users: they are older and often busy with their own work (including back-end maintenance of the site). They don't hang out or look for opportunities to chat as much as the regular kids do. They do, however, serve the important role of providing supervision, encouragement, and technical help to new users.

The result that we found most interesting is the apparent synergistic effect that talking to both administrators and regulars has on the participation metrics of new MOOSE Crossing users. Groups whose members conversed with both administrators and regulars within their first few conversational partners consistently performed well, as judged by both the number of communication commands they entered and the number of days they logged in. The types of social support provided by administrators and regulars seem to be complementary, and together strongly engage and motivate new users.

Conclusion

Practically, the results presented here speak to the importance of supporting, fostering, and rewarding an online community's regulars. In synchronous, self-motivated, collaborative learning environments, like MOOSE Crossing, regulars often act as an unofficial welcoming committee and support desk for new users. In these spaces, other human users command much more attention than tutorials, on-line help, or any other inanimate form of support provided by the system's designers and organizers. The more we understand the informal support provided by regulars, the more we as designers of online systems can help support these key roles.

We encourage readers interested in an in-depth discussion of the issues presented in this paper to view the associated technical report (Medynskiy & Bruckman, 2007).

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An Efficient and Flexible Technical Approach to Develop and Deliver Online Peer Assessment

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Abstract: Peer assessment is a special form of collaborative learning, in which peer students learn through assessing others' work. Recently, the design of collaboration scripts is a new focus area within the CSCL community. In this paper, we present a method based on open e-learning standards to script peer assessment processes. A standard-compatible tool can help users to script various forms of peer assessment in a machine-interpretable form. Such peer assessment scripts then can be executed on today's open technical e-learning infrastructure. In comparison with typical software development approaches to support online peer assessment, this technical approach is more efficient and flexible.

1. Introduction

Falchikov (2001) defines peer assessment as "the process whereby groups rate their peers". Somervell (1993) states that peer assessment engages students in making judgments on the other students' work. Researchers have generally agreed that peer assessment stimulates student motivation and encourages deeper learning and understanding (Freeman 1995; Topping 1998; Pope 2001). As Weaver and Cotrell (1986) pointed out, peer assessment can be seen as a means by which ability in the learner to make independent judgments of their own and others' work can be developed and practiced. A peer assessment can encourage a greater sense of involvement and responsibility, establish a clearer framework and promote excellence, direct attention to skills and learning and provide increased feedback. Peer assessment can be seen as a special type of collaborative learning (Freeman 1995; Brindley and Scoffield 1998; Keppell, Au et al. 2006). It not only promotes students' confidence in their ability to assess the work of others, but also provides the opportunity to develop skills for working in a team. In principle, no a single form of peer assessment can fit all situations. In practice, various forms of peer assessment are designed and used.

Although peer-assessment may be a comprehensive learning process in some ways, there are also some identified pitfalls (Falchikov 2002). Many of the associated problems may occur because it is a complex procedure and students are not very experienced to conduct peer assessment. The success of peer assessment depends greatly on how the process is set-up and subsequently managed. In recent years, many computer-based tools have been developed for supporting peer assessment. For examples, Many Using and Creative Hypermedia system (MUCH) (Rada, Acquah et al. 1993; Rushton, Ramsey et al. 1993), Peers (Ngu, Shepherd et al. 1995), Peer Grader (PG) (Gehringer 2001), and Self and Peer Assessment Resource Kit (SPARK) (Freeman and McKenzie 2002) are multi-user tools that support collaborative learning and have been successfully used to undertake peer assessment. These software tools are developed in a typical software development method. Normally, software developers make quite a lot efforts and invest much time to develop a peer assessment tool. In addition, after a tool is developed, it is difficult to change and add new functions to fit changing learning contexts and specific needs.

Recently in CSCL community, the design of collaborative learning scripts is a new focus area. The basic idea is to describe collaboration processes formally by using a scripting language and then to scaffold a group of students communicate and collaborate by executing collaboration scripts (O'Donnell and Dansereau 1992; Dillenbourg 2002; Kollar, Fischer et al. 2005; Miao, Hoeksema et al. 2005; Weinberger, Stegmann et al. 2005). However, so far there is no scripting language which is suitable to model various forms of peer assessment (see next section) and furthermore no corresponding system provides rum-time support. In this paper, we present an approach based on today's open e-learning standards to develop and deliver online peer assessment. In comparison with typical software development approaches to support peer assessment, we argue that our approach is more flexible and efficient. This paper is organized as following. First, we briefly introduce peer assessment and analyze the characteristics of peer assessment from the perspective of collaboration scripts. Then we present an open e-learning standard based approach to support peer assessment. We present how users will be supported to script a peer assessment process by using an authoring tool and to execute a peer assessment script in today's open technical e-learning infrastructure. After discussing the advantages and disadvantages of this approach, we present conclusions and indicate the future work directions.

2. Various Forms of Peer Assessment

As mentioned above, there are various forms of peer assessment available. The variables could include levels of time on task, engagement, and practice, coupled with a greater sense of accountability and responsibility (Topping, Smith et al. 2000). To analyze the characteristics of peer assessment, we used Topping's aforementioned typology (Topping 1998), shown in Table 1. This typology consists of a survey of variables found in reported systems of peer assessment in higher education.

Table 1: A typology of peer assessment in higher education (Topping 1998)

No.	Variable	Range of Variation
1	Curriculum area/subject	All
2	Objectives	Of staff and/or students? Time saving or cognitive/affective gains?
3	Focus	Quantitative/summative or qualitative/formative or both?
4	Product/output	Tests/marks/grades or writing or oral presentations or other skilled behaviors?
5	Relation to staff assessment	Substitutional or supplementary?
6	Official weight	Contributing to assessee final official grade or not?
7	Directionality	One-way, reciprocal, mutual?
8	Privacy	Anonymous/confidential/public?
9	Contact	Distance or face to face?
10	Year	Same or cross year of study?
11	Ability	Same or cross ability?
12	Constellation Assessors	Individuals or pairs or groups?
13	Constellation Assessed	Individuals or pairs or groups?
14	Place	In/out of class?
15	Time	Class time/free time/informally?
16	Requirement	Compulsory or voluntary for assessors/ees?
17	Reward	Course credit or other incentives or reinforcement for participation?

In this section we investigate these variables from the perspective of scripting peer assessment. Some variables have no directly effect on scripting. They can be treated as certain kinds of metadata for describing and retrieving scripts. These variables are var. 1, var. 2, var. 6, var. 9, var. 10, var. 12, var. 13, and var. 14. Then we clustered the reminding variables into two categories: task-relevant variables and process-relevant variables.

2.1. Variety in Assessment Tasks

The variable concerning assessment tasks is variable 4. Various types of tasks may be performed in peer assessment for both providing evidences and for giving feedback. The usual task types, as described in variable 4, are tests/marks/grades or writing an essay. As reported in (Kane and Lawler III 1978), different types of tasks can be performed in peer assessment: peer ranking, which consists of having each group member rank all of the others from best to worst on one or more factors; peer nomination, which consists of having each member of the group nominate the member who is perceived to be the highest in the group on a particular characteristic or dimension of performance; and peer rating, which consists of having each group member rate each other group member on a given set of performance or personal characteristics, using any one of several kinds of rating scale. In knowledge convergence script (Weinberger, Fischer et al. 2004), peer students use open-questions to write articles and to comment on peers' articles as well.

In addition, variable 4 mentions oral presentations or other skilled behaviors. That is, in an online peer assessment, task-specific application tools may be used to demonstrate their progress and capabilities and to evaluate peers' work. Pellegrino, Chudowsky et al (2001) described the use of concept mapping to assess knowledge structures, or the use of latent semantic analysis to interpret student essays. Therefore, scripting peer assessment requires explicitly modeling various types of tasks.

2.2. Variety in Assessment Processes

Peer assessment that are embedded in an institutional context, require more stipulation of the processes of assessment and rely on higher levels of student involvement (Sluijsmans, Brand-Gruwel et al. 2004). Var. 5 concerns whether staff is involved in the process and what a kind of role s/he will actually has. Variables concerning the composition of the feedback groups are var. 11, var. 12, and var. 13. Variables concerning the interaction of the students are var. 7 and var. 8. In peer assessment processes, various tasks are carried out by many students with multiple roles in sequence or in parallel. A large quantity of information is produced in performing various tasks in different phases. Students interact with each other through exchange of information. They may exchange in one-way, reciprocal, or mutual manner. In knowledge convergence script (Weinberger, Fischer et al. 2004), peer students transfer their articles and comments in a rotate manner. Variable 3 concerns whether a peer assessment is integrated with other learning activities. Peer assessment has a vital role to play in formative assessment, but it can also be used as a component in a summative assessment package. Therefore, in order to support online peer assessment, a complex workflow with the involvement of multiple users/roles should be modeled.

In summary, there are various forms of peer assessment. They vary in using different task types and in different interaction processes. Basic requirements to script peer assessment are to model various types of assessment tasks and various forms of group interaction.

3. An Approach Based on Open E-learning Standards

This section presents two open e-learning standards which are suitable to support various types of assessment tasks and various assessment processes, respectively. Our approach is based on these two international e-learning standards.

3.1. IMS Question and Test Interoperability

The IMS Question and Test Interoperability (IMS QTI 2006) is an open e-learning standard which describes a data model for the representation of question (assessment_item) and test (assessment_test) and their corresponding results reports. The diagram below the dash line in Figure 1 illustrates the main concepts and their relations. For the purpose of this paper, we omit a lot of detail of IMS QTI conceptual model. General speaking, an assessment_test consists of a set assessment_items. An assessment_item contains not only information about question itself, but also relevant information such as time_dependent, adaptive, stylesheet, modal_feedback, and some kinds of declarations. In Figure 1, only item_body (representing questions) and outcome_declaration (representing results like a score), response_declaration (capturing user's response), and response_processing (handling results according to user's responses) are drawn and emphasized. An item_body can have one or more interactions. IMS QTI defines a set of interaction types such as choice_interaction, text_entry_interaction, extended_text_interaction, match_interaction, order_interaction, slider_interaction, an so on. Each interaction is associated with a response variable which captures user's response. User's responses will be used to determine the outcome according response_rules (not drawn in Figure 1) specified in response_processing. So IMS QTI provides sufficient flexibility to grow into the advanced constructed-response items and interactive tasks we envisage as the future of assessment elaborates the assessment items in detail (Almond, Steinberg et al. 2001). Furthermore, it provides mechanisms to design structured assessment and control branches and calculate weighted scores. That is, various types assessment tasks and even structured assessment tasks needed in peer assessment can be supported by using IMS QTI tools.

However, IMS QTI is concerned with individual learners only, although it does not prohibit usage in contexts involving other actors (e.g., instructors, supervisors, and peers). It does not support explicitly the definition of a variety of roles or sequencing behaviors that result from participation of other actors. Therefore, it can not be used to support the multiple roles/users interaction that are needed to model peer assessment. Additionally, IMS QTI does not support specific assessment tasks which need specific assessment tools.

3.2. IMS Learning Design

IMS Learning Design (IMSLD 2003) is an open e-learning standard based on the Educational Modeling language (EML) developed by Open University of the Netherlands (Koper 2001). The diagram of upper part in Figure 1 (excluding grey rectangles) illustrates the main concepts and their relations in IMS LD. It is a conceptual model represented by using UML notations. Some concepts (e.g., learning objective, activity-structure, and concrete expressions) and some relations (e.g., hierarchical structure of role or environment, association relation between act and notification) are not shown in Figure 1 for the sake of simplicity and readability. As illustrated in Figure 1, a learning design (unit of learning is its operational object with necessary resources) consists of a set of components such as roles (including learners and staff), activities (including learning activities and support activities), environments (containing learning objects and services), and properties (including personal, role-based local-/global-properties, not shown in Figure 1). They are organized by using theatrical metaphors like plays, acts, and role-parts as a hierarchically structured and process-oriented method. Conditions, as a part of the method, consist of expressions (e.g., logical expressions, arithmetic expressions, and IMD LD specific expressions not shown in Figure 1) and actions (e.g., show/hide, notification, and change-property). IMS LD is a pedagogical neutral language which can be used to model a wide range of pedagogical strategies (Koper and Olivier 2004). In general, IMS LD can be used to script different forms of group interaction involved with multiple roles/users.

Although EML can support assessment, however, assessment tools and strategies are excluded in IMS LD (IMSLD 2003) when it was adopted by IMS (considering the existence of IMS QTI). As a consequence, IMS LD can not explicitly model various types of assessment tasks within a peer assessment process. However, IMS LD supports to include assessment content. In addition, as illustrated in Figure 1, IMS LD offers an approach to integrating application tools as services. Although only four internal services are explicitly specified in IMS LD, in theory, any software tool can be integrated in a learning design as an external service. Therefore, with an appropriate interface, any specific assessment tool (e.g., a concept-mapping tool or a simulator) can be integrated into a unit of learning.

3.3. Supporting Peer Assessment through a Combined Use of IMS QTI and IMS LD

IMS QTI version 2 provides the possibility to integrate IMS QTI with IMS LD. The primary motivation for integrating IMS LD and IMS QTI stems from use cases involving formative assessment and summative assessment using items with traditional question types (IMSQTI 2006). We extend the application areas of an integration of IMS LD and IMS QTI and improve the benefit of their combined use. As a consequence, a peer assessment can be modeled as a unit of assessment, a special unit of learning with assessment-specific entities.

Figure 1 shows an extended IMS LD conceptual model with an integration of IMS QTI. The grey rectangles represent extended assessment-specific concepts. A unit of assessment contains, at minimum, one assessment activity performed by assessee or assessor in a manner exploiting IMS QTI documents or/and assessment-specific services. It is important to note that such an extension is at conceptual level, without changing IMS LD at operational level except to explicitly add a new resource type “imsqti”. For example, an assessment activity should be defined still as a learning activity or a support activity. Assessee or assessor will be defined as sub-roles of staff or/and learner in a normal way. If an external service will be used as an assessment tool, it will be defined in a normal way to specify other external services. Only if a QTI item such as a multiple-choice, an ordering, or an open-question will be used in the assessment activity, the definition of the resource has to be handled in a IMS LD-aware manner. As illustrated in Figure 1, a resource referring to an assessment_test or an assessment_item has to be explicitly defined as an “imsqti” type. With such an indication, the run-time environment will call a QTI player as a generic assessment service to render questions according to the referred QTI document. In addition, any assessment-relevant property in IMS LD should be defined in a way that the identifier of the property is defined as a combination of the identifier of the assessment_item and the identifier of the outcome. In this way, a property and a outcome will be coupled. Three solid lines represent the connections between IMS LD and IMS QTI.

When scripting a peer assessment through such a combined use of IMS LD and IMS QTI, a peer assessment can be modeled and wrapped as a special unit of learning, which include a set of coordinated learning activities, support activities, and assessment activities performed by a group of peer students (and sometimes including tutor). An assessment activity may be performed by using a specific assessment service or by referring a

QTI document directly in its activity-description or indirectly through a learning object within an associated environment (see Figure 1). The scripted peer assessment then can be delivered in an integrated execution environment. The following two sections will present this approach in detail using a peer assessment example.

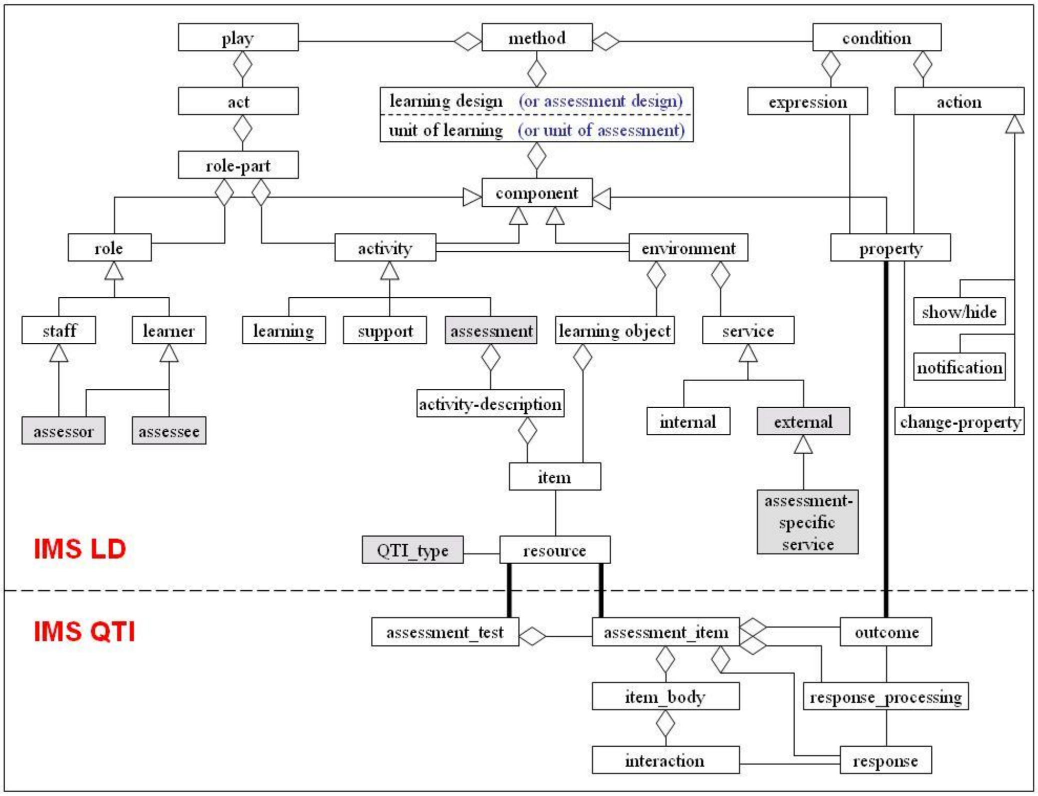

Figure 1. Extended IMS LD Conceptual Model with Integration of IMS QTI

4. Scripting a Peer Assessment

4.1. A Peer Assessment Example

For the purposes of presenting modeling method, a case study is introduced that is originally described in (Orsmond 2004). This case study describes a peer assessment exercise – writing and reviewing an article for a scientific magazine. The following steps describe the principal stages:

1. A tutor explains the peer assessment procedure and instructs students to select an interesting, recent paper from the primary scientific literature.
2. Each student selects a different paper and reads it.
3. Each student then prepares a brief article (400-500 words) about their chosen paper in the style of the "This Week" section of New Scientist magazine.
4. Pairs of students then exchange articles and review each other's work, using an evaluation sheet very similar in overall style to that used by scientific journals. The reviewer must assess the article and (i) decide whether the article is acceptable without change or whether minor/major revision is required (ii) provide specific feedback on any points raised by commenting on the article.
5. Student reviewers then return the article and evaluation sheet to the original author, who has then to consider their response to the review, using a response form. Students must decide whether to (i) modify their article, whether they feel that the reviewer's comments are appreciate and (ii) prepare a written response to each of the points raised by the reviewer. Then students hand in all documents for final assessment.
6. The tutor then marks on students' exercises in a way that the quality of the original version of the article, the student's response to peer review, and the student's effectiveness as a peer reviewer will be considered as 30%, 30%, 40% of the overall mark, respectively.

4.2. Scripting the Peer Assessment Example by Using an Authoring Tool

The peer assessment example is modeled and shown in Figure 2. In this peer assessment example there are two kinds of roles: tutor and learner. In order to explicitly model the tasks of each peer student and the exchange of information between them, learner1 and learner2 are defined as two sub-roles of the learner. The tutor and peer students are assigned to do different tasks. The tasks are modeled as learning activities (e.g., selecting/reading paper1 and responding review1) and support activities (e.g., final assessment1) in the model. Each activity has an element called activity-description, some of which (e.g., writing article1 or reviewing article2, final assessment2) refer to QTI documents. The overall assessment process is defined as a play with six acts illustrated in the Figure 2. Each act consists of more than one role-part. In the first act, the tutor teaches learners how to conduct this peer assessment and what is expected. In the second act, two peer students select a different paper respectively and read the selected papers. In the third act each student writes an article. In the fourth act students review the articles of their peers and comment on them. In the following act they response to the reviews of their peers and revise the original article if necessary. In the last act, the tutor assesses the students' work and give them scores. All acts are executed in sequence. The arrows with solid lines in Figure 3 indicate the control-flows of the process

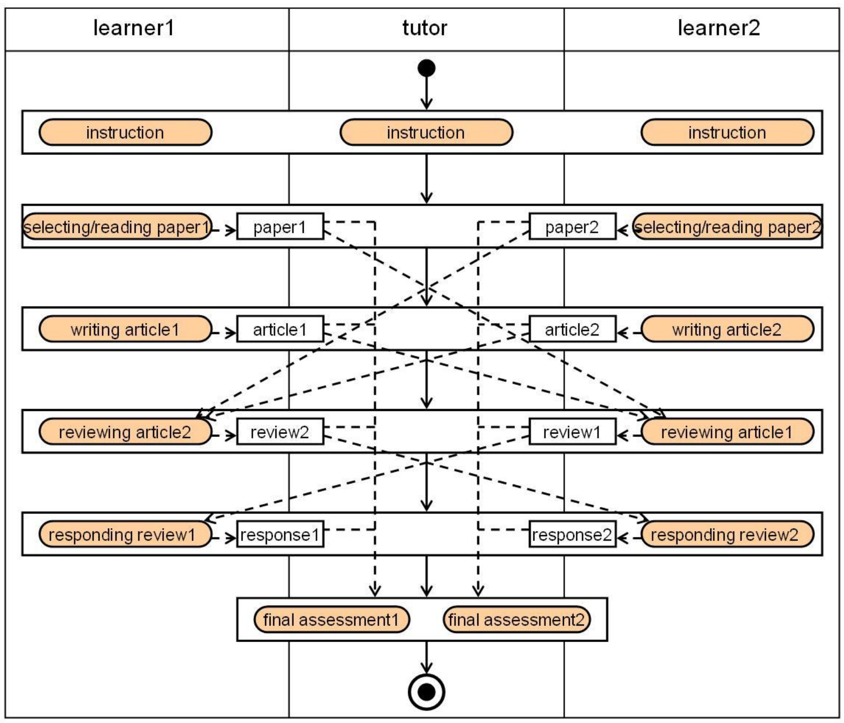

Figure 2. Process Model of a Peer Assessment Example

Properties should be defined to represent products and assessment results (e.g., article1 and review1) in the peer assessment script. Meanwhile, corresponding outcome variables of assessment_items have to be defined as well. The identifier of a property titled articile1 has to be defined in a way like article1_qtiitem.content by combining identifier of assessment_item (defined as article1_qtiitem) and identifier of outcome (defined as content). Such definition enables data transference from QTI document to IMS LD property. In addition, as we see in Figure 2, data (e.g., article1, article2, review1, review2, and so on) are produced by a learner in an activity and will be used by another learner in another activity. The arrows with dash lines indicate the data-flows in the process. Viewing the value of a property is realized by using "view-property" element in a XHTML document, which is modeled as a learning resource and will be referred by an item. The item is defined in a learning object within an environment. We define two environments for storing data regarding to the work of two learners, respectively. For example, the environment named "information about article1" will be associated with all activities handling article 1 such as selecting/reading paper1, writing article1, reviewing article1, responding review1, and final assessment1. Since all data concerning article 1 is collected in this environment, this shared environment can be used by learner1 writing article1, by learner2 reviewing article1, and by tutor assessing learner1's work.

An compatible authoring tool can be used to script this peer assessment and then to generate IMS LD code and IMS QTI documents automatically. This tool is developed based on CoSMoS (Miao 2005), a tree-form-based IMS LD authoring tool and now is extended to integrate functions for editing IMS QTI item. Although not all QTI edit functions have been developed, as shown in Figure 3, a user can script a learning design and edit necessary QTI documents in an integrated authoring environment with a unified user interface. The Figure 3 shows the user interface of editing the review form with a multiple-choice interaction and an open-question interaction. It is important to note that the coupling of a property (e.g., comment1) in peer assessment script with an outcome variable (e.g., comment) in the assessment_item titled "review1" can be defined by dragging the icon of the property and dropping into the input-filed of outcome. Then the identifier of the property titled "comment1" will be assigned as "review1.comment" automatically.

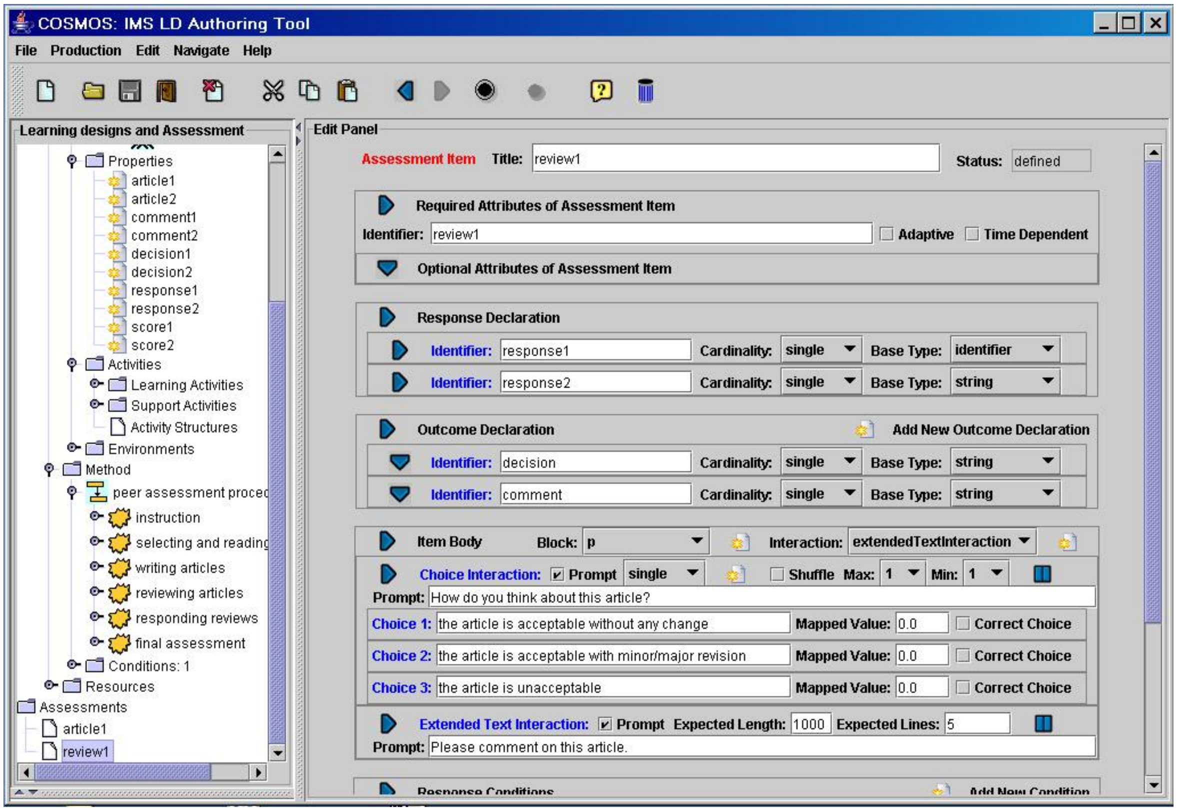

Figure 3. A Screenshot of an Integrated IMS LD and IMS QTI Authoring Tool

5. Delivering a Peer Assessment

This peer assessment example has been executed successfully in a web-based, integrated execution environment including Service-based Learning Design Player (SLeD 2004), an IMS LD client, CopperCore (Vogten and Martens 2004), an IMS LD engine, and APIS (APIS 2004), an IMS QTI player. They have been integrated through CopperCore Service Integration Architecture (CCSI) (Vogten, Martens et al. 2006). CCSI was developed with the integration of different kind of services in mind, especially those defined in the service section of LD although other types of services are conceivable. In the execution of the peer assessment, a user interacts with SLeD in a normal way to play a learning process following the script. When a QTI document is used, the CopperCore engine will send the QTI document to SLeD. Then SLeD will ask for service from APIS player and render corresponding question for the user. When user finishes the answering the question, SLeD will send to APIS again for handling user's response. The results will be transferred to CopperCore according the coupling between the property and outcome defined in the script. The detail handling procedure can be seen in (Vogten, Martens et al. 2006). Figure 4 shows a screenshot of the user interface when learner2 is reviewing article 1.

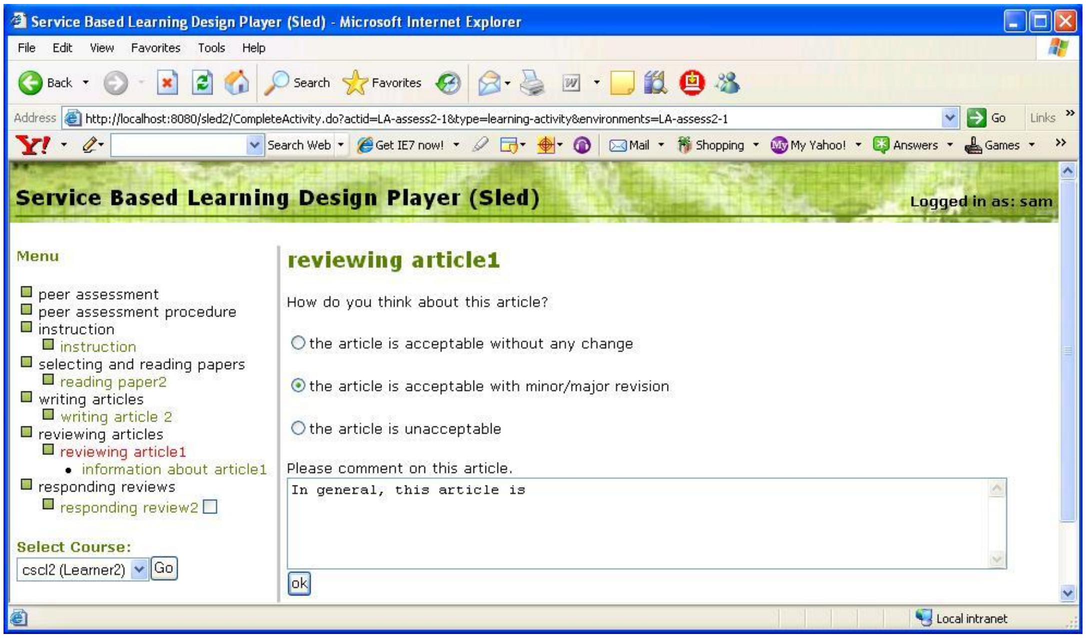

Figure 4. A Screenshot of Execution of the Peer Assessment Example

6. Discussion

In this section we discuss two issues: efficiency and flexibility. *Efficiency*: Rather than educational efficiency of a peer assessment, we discuss efficiency of technical approaches to develop and deliver an online peer assessment. As mentioned before, in typical software development methods, developers with programming competence has to spend about one man-year to design, code, compile, debug, and install a peer assessment tool. Our approach is fully based on open e-learning standards. As we have seen, standard-compatible authoring tools and run-time environments are available. The users with knowledge about programming and process modeling can be trained easily to script online peer assessment by using tools. To script a peer assessment process, one or several days may be enough for users who have process modeling competence that is possessed by most software programmers. In addition, because of interoperability, users can design a peer assessment based existing scripts of others through searching and modifying. It will extremely save a lot of time and efforts in development of online peer assessment. *Flexibility*: we discuss the flexibility of technical approach to develop and deliver a online peer assessment. As discussed in the second section, there are a variety of forms of peer assessment. The variation space of peer assessment is a combination of all variables changing in their value domains. Any software tool can only provide a limited flexibility. Additionally, once a software application tool has been developed, it is not easy to customize and add new functions to fit the changing contexts and specific needs. These software applications have their own data representation that is not usable by other applications. Their functions cannot be shared directly by other software tools as well. In contrast, our approach is based on open e-learning standards. A peer assessment script can be tailored and customized easily for their special requirements. They can be executed in any IMS LD player with any integrated IMS QTI player.

This technical approach has limitations. The required level of technical knowledge of IMS LD and IMS QTI for those authoring assessments is significant at the moment, because of the lack of easy to use graphical tools that support users in complex learning models. To acquiring such knowledge is not very difficult work for software developers and people with knowledge about programming and process modeling. However, when we try to extend a user group to include end-users like teachers and assessment designers, there is still a gap between the requirements of users and the functions that existing authoring tools can provide. In addition, if group interaction is extremely complex (e.g., in group composition, group dynamics, data structure of evidence, and data exchange patterns) and the number of roles and peer students increases, the complexity of the scripts will be too difficult to be handled even for experts. Therefore, new generations of authoring tools are expected to support practitioners to develop online peer assessment. One of the aims of the TENCompetence project (TENCompetence, 2006) is to develop such authoring tools.

7. Conclusions and Future Work

Peer assessment is a special pedagogical method that can be applied to develop critical thinking skills and improve communication skills. There is no such a form of peer assessment that "one size fits to all". Many different forms of peer assessment have been designed and reported. Existing tools supporting online peer assessment are developed in a typical software development method. A lot time and efforts will be spent for developing the tools. In addition, they can not be easily customized to fit the changing contexts and specific needs. We claim that a technical approach based on open e-learning standards can make the development and delivery of a peer assessment more efficiently and flexibly. In this paper, we analyze the strength and weakness of IMS QTI and IMS LD on supporting online peer assessment. We present a technical approach to script multiple users/roles involved group interaction needed in peer assessment by using IMS QTI and IMS LD complementarily. In order to help users to get benefits from this approach, design-time systems and run-time systems are developed and under development. Through using a peer assessment example, we present how users can be supported in scripting a peer assessment and in executing a peer assessment script. Through a discussion, we conclude that our approach based on IMS QTI and IMS LD, in comparison with typical software development methods, is a more efficient and flexible method to support online peer assessment.

However, existing IMS LD and IMS QTI authoring tools can not support average practitioners to script their own peer assessment. Our future work in this direction is to develop domain-specific language to represent the various facets of peer assessment. Such a language tends to support higher-level abstractions than general-purpose modeling language like IMS LD and IMS QTI, meaning that they require less effort and fewer low-level details to script a peer assessment. The scripts in such an assessment-specific language will be transformed into IMS LD code and QTI documents automatically, wrapped as a unit of assessment, and delivered in any standard-compatible execution environment.

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Acknowledgments

The work on this paper has been sponsored by the TENCompetence Integrated Project that is funded by the European Commission's 6th Framework Programme, priority IST/Technology Enhanced Learning. Contract 027087

ProBoPortable: Does the Cellular Phone Software Promote Emergent Division of Labor in Project-Based Learning?

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Abstract: This paper describes the design and evaluation of a cellular phone application called “ProBoPortable”, which displays information regarding the task status and division of labor in a project-based learning (PBL). The authors have developed a cellular phone application that cooperates with a Web-based groupware to enhance the learners’ reorganization of learning activity in PBL. The research conducted in an undergraduate course revealed that ProBoPortable can enhance awareness regarding the status of learners’ collaborations in PBL.

Introduction

In recent years, the project-based learning (PBL) is being extensively used as a major educational method in higher education (Gijbels, et al., 2005). PBL is a type of learning activity in which learners study along with other learners whilst working toward a common goal and collaborating on tasks as a group. Throughout the PBL, the learners rarely share the same task parallel with that of other learners. They prefer to divide a certain part of the task into smaller tasks and allocate each task to individual group members.

Even in cases where the rules for division of labor are institutionalized by a teacher or an organization, people sometimes cross the borders of the division and coordinate their tasks across the borders with other people as the occasion may demand. For instance, if the task monitor gives the task performer some instructions when the monitor notices the task performer’s errors, it implies that the monitor becomes involved in performing the task. Thus, division of labor is reorganized in a more or less ad-lib and ad hoc manner in order to progress the task uninterrupted and error free. Kato et al. (2004) termed such a cross-over of division of labor as “emergent division of labor (EDL).” They argued that EDL should provide rich opportunities for learning wherein scaffolding takes place naturally, and EDL is subject to occur in open environment where the learners can see what they do each other.

However, in Japanese universities, undergraduate students get very little time to interact with each other on campus; for example, they can meet only in the classroom, while eating lunch, etc. Therefore, the authors have developed a web-based groupware for PBL called “ProBo” (formerly “Project Board”), in order to enhance the learners’ recognition of their EDL in both classrooms and distributed environments. ProBo has been designed to visualize and allocate tasks among the learners in a group. The practical evaluation revealed that ProBo promoted the learners to monitor their personal learning activity but the other members’ activities in the group. (Nishimori, et al., 2005).

Design and Development of ProBoPortable

In order to enhance the awareness among the learners for the EDL, the authors designed and developed a cellular phone application called “ProBoPortable,” which is based on ProBo. ProBoPortable was designed to work as wallpaper on the learner’s cellular phone screen in order to keep them updated as regards to the progress of their project and stimulate the division of labor as soon as the requirement or inevitability arises. In accordance with the requirements of the EDL, the authors selected the necessary information to confirm and reorganize the division of labor, such as the number of tasks to be completed by each learner, the progress of each task, etc. (see Table 1).

ProBoPortable describes the learners who have to complete their tasks as warehouse keepers (see Figure 1). If a learner performs a task, the corresponding box shifts slightly. The other learners can observe this change when they activate their cellular phones. When two or more learners collaborate to perform a task, the corresponding box in each of their positions moves. When the learner(s) completes the task, the corresponding box drops down and the amount of money increases; all the learners can observe the completion of the task. In accordance with the requirements of the EDL, ProBoPortable indicates whether each learner has confirmed his/her status of the PBL via ProBo or ProBoPortable. Thus, the learners are expected to observe the status of the other members on a daily basis, perform their tasks, and reorganize their division of labor as and when required.

Table 1: Relationship between Visualized Information on ProBoPortable and ProBo.

Information	Index	Target	Expression
Member(s)	Each member	Warehouse keepers and their facial colors	Each of the members is color-coded
Number of Tasks	Number of boxes	Box(es)	If a new task is added on ProBo, a new box is added from above
Progress of each task	Shift length	Box corresponding to the task	If a learner carries forward a task, the corresponding box shifts slightly
Approaching the time limit for the task	Color (normal or red)	Corresponding box	If the deadline approaches, the color of the corresponding box changes to red
Progress of the project	Background color (normal or red)	Backgrounds of all the members of the project	If the progress of the project shows a lower value than the benchmark, the color changes to red.
	Money	Amount of money	If the task is completed, the amount increases
Whether or not each learner has confirmed the status	Background color (of relevant learner(s))	Relevant learner(s)	If the learner has not confirmed the status of EDL via ProBo/ProBoPortable, his background color changes to black

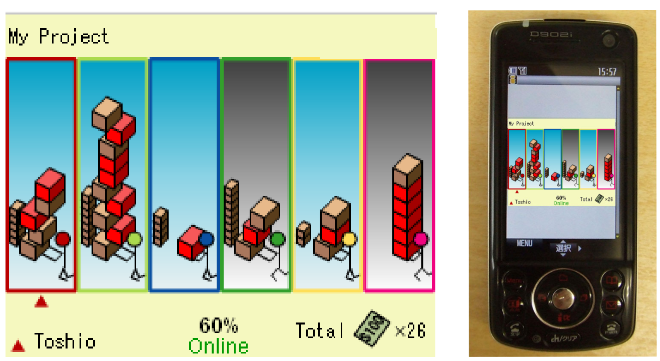

Figure 1. ProBoPortable Interface (displayed on the cellular phone screen)

Evaluation of ProBoPortable in an Undergraduate Course

The research was conducted in an undergraduate course taught by one of the authors as an adjunct lecturer at a university in Japan. The research took place between June 5 and July 10, 2006, during which each section met six times. The common objective of each group was to conduct a presentation on the current situation and the prospects of one of the various topics associated with information communication technology. Each group had to conduct a survey on the assigned topic and make suggestions on the topic for future society. A total of 94 students participated in the course. The students were divided into 20 groups, each group comprising 4 to 6 individuals.

This research was formulated using the split-class design (Carver, 2006) to evaluate the software being used in the classroom with respect to the context of the course taught in the classroom. At the beginning of the evaluation, the authors announced that students taking the class could participate in this evaluation. Based on the group structure and the preferred topics, the authors selected 11 students from those who applied for their cooperation in the research. ProBoPortable was installed in each of these 11 students' cellular phones, which they had been using from before. ProBoPortable worked and appeared in the background color of their cellular phone throughout the four-week period starting from June 12. They also used ProBo with other students.

The authors analyzed the operation log of all the students operating ProBo and ProBoPortable from June 12 when they started using the ProBoPortable through July 10. In addition, the questionnaire was administrated after the final class; this contained self-evaluation of PBL regarding the awareness of division of labor during group work.

Results: Does ProBoPortable Promote Awareness among Learners for EDL?

In order to accurately confirm the effect of ProBoPortable, the Mann-Whitney U-test was administered to examine the differences between students who used ProBoPortable (n = 11, hereafter referred to as "Experimental Group") and those who did not (n = 83, hereafter referred to as "Control Group"), with regard to the students' self-evaluation of their PBL on a 5-point Likert scale (1: strongly disagree – 5: strongly agree).

According to the test results, significant differences were observed in items as "I was aware of the progress of each task undertaken by the other members" (Experimental Group ave.= 4.55, Control Group ave.= 3.17, U = 138.0, $p < .001$), "I think that the other group members were also aware of the progress of my tasks" (Experimental Group ave.= 3.72, Control Group ave.= 2.75, U = 172.5, $p < .01$), and "I have adjusted the pace of my task according to the others' pace, which I monitored" (Experimental Group ave.= 3.45, Control Group ave.= 2.43, U = 233.0, $p < .01$). These results indicated that the ProBoPortable was effective in not only understanding others' task status but also confirming whether or not the others were aware of one's progress in the task, and to flexibly adjust one's own task as necessary by a continuous monitoring of others' status as well as one's own.

On analyzing the operation log (the number of people accessing each function per day) of ProBo, significant differences were observed between Experimental Group and Control Group with regard to the access of the ToDo list, which structures the PBL tasks, (the Experimental Group averaged 0.175 times, Control Group averaged 0.101 times, U = 273.5, $p < .05$) and the Scheduler, which confirms the prospects of PBL (Experimental Group averaged 0.357 times, Control Group averaged 0.142 times, U = 311.0, $p < .05$). The group using the ProBoPortable also exhibited higher points with regard to the number of accesses to the profile of a task (Experimental Group averaged 1.11 times, Control Group averaged 0.86 times) and the number of times to a task was modified (Experimental Group averaged 0.12 times, Control Group averaged 0.08 times), although no significant statistical difference was observed. Therefore, the results suggest that ProBoPortable promoted the self-review of the entire PBL task structure.

Furthermore, significant differences or trends were observed with regard to items such as "From time to time, I wanted to talk with other member(s) outside the classroom to negotiate the protocol for further project proceedings" (Experimental Group ave. = 4.09, Control Group ave.= 3.39, U = 250.0, $p < .05$) and "I frequently contacted other group member(s) outside the classroom in connection with the group activities" (Experimental Group ave.= 2.73, Control Group ave.= 2.02, U = 274.0, $p < .10$). It suggests that ProBoPortable presents opportunities to generate learning activities and mutual adjustment outside the classroom.

These results demonstrate that the mutual confirmation of the task status by using ProBoPortable stimulates the relative evaluation of one's own task status and encourages one to perform ones own tasks.

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Acknowledgments

A part of this research has received assistance of Grant-in-Aids for Scientific Research (B) (Subject No. 16300280, representative: Hiroshi Kato), and for Young Scientists (B) (Subject No. 17700607, representative: Toshio Mochizuki), from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

Source Memorization in Chat Interactions

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Abstract: This paper reports a study about memorization of online chat interaction. Results show that subjects are very good at recognizing who produced a given utterance, especially if they produced the utterance themselves. Performance was much weaker when subjects recalled who produced the utterance immediately following the given utterance. We investigated several variables in order to predict which utterances are easier to remember.

Introduction

The learning outcomes in collaborative settings are related to the quality of interactions, mostly verbal interactions. Therefore, our CSCL research agenda includes basic questions such as how memory may impact social interaction and collaborative processes. If we take a Vygotskyan perspective, the internalization of conversations requires memorizing them in one way or another. According to Miller and deWinstanley (2002), memory processes are involved in maintaining coherence in conversations. Imagine a person who has difficulty remembering who said what to whom and when during a discussion. This person runs the risk of repeating information and failing to actively collaborate in the co-construction of meaning. The ability to retrieve conversation exchanges from memory is also important in a situation where various people talk at the same time via a chat tool. Pimentel, Fuks and Lucerna (2003) used the terms "co-text loss" to designate the phenomenon that occurs during a chat when participants are unable to establish a conversation thread. According to Horton and Gerrig (2005), the way speakers adapts their utterances to their audience, depends upon the accessibility in memory of the mental representation the speakers constructed about their addressees' knowledge, needs, etc. They also assumed that during interaction, individuals could use their partners as contextual cues to retrieve information they share with them. How do interlocutors memorize their interactions? What characterizes the chat utterances that people remember best? These questions are at the core of collaborative learning mechanisms but haven't received much attention in our community. This contribution reports on investigations we conducted in task-oriented chat discussion between three students.

Method

Studies that investigate conversation memory usually include two phases: a discussion phase and a testing phase (e.g., Keenan, MacWhinney, & Mayhew, 1977). In the first phase, either participants are presented with a written transcription of a discussion, or are asked to participate in a discussion. In the second phase, two types of tests can be used to evaluate whether subjects have memorized either the content of conversation (content memory) or the speaker of a particular utterance (source memory): a recall test or a recognition test. This contribution concerns source memory (our experiment addressed both measures but we focus on the latter). We used a prime-target paradigm to investigate the influence of memory activation upon retrieval. To our knowledge, this paradigm had not been used to investigate interaction memory. During the discussion phase, subjects had to design a working space dedicated to students by taking various constraints into consideration. In our testing phase, participants were first provided with a prime utterance automatically extracted from the transcript of their conversation (a chat). Half of the participants were asked to recognize who said the prime (experimental condition) whereas the other half was assigned to a control condition (no prime speaker recognition). Second, all participants had to recall the speaker of the target utterance, that is, the utterance that immediately followed the prime and then to recall the content of the target. We only report here the results regarding memory for the two speakers (source memory), that is, the prime and the target speakers. The independent variables are the fact that subjects in the experimental group had to recognize the prime speaker as well as several features (see below) used for selecting the primes from the chat conversations.

Hypotheses

Based on Horton and Gerrig studies (2005), we hypothesized that asking participants to identify the speaker of the prime (experimental condition) would facilitate retrieval of the target speaker (H1: *prime speaker effect*).

Two factors frequently identified as influencing memory for conversation are distinctiveness and cognitive effort (e.g., Keenan et al., 1977; Klauer, Wegener, & Ehrenberg, 2002). Memory is higher for conversational sentences that are different in some way (e.g., high interactional sentences). Regarding source memory, it seems that the more distinctive two or more speakers are, the easier it would be to separate their respective contributions. Based on these findings, source memory would be better (a) for conversational utterances that are highly speaker-specific, i.e., for utterances that contain words mostly produced by one speaker during the discussion (H2: *speaker specificity effect*), and (b) for long utterances that usually require more processing effort (H3: *utterance length effect*).

Previous studies on interaction memory also revealed two effects, namely the *order effect* (Igou & Bless, 2003) and the *generation effect* (Miller & deWinstanley, 2002). Primacy (versus recency) effects should occur if participants expect that the most important information should be given at the beginning (versus the end) of the conversation (H4: *order effect*). The generation effect concerns memory for our own contributions during interaction. We thus hypothesized that memory performance would be higher for self-generated than for partner-generated utterances (H5: *generation effect*). This effect – as well as those previously presented (speaker specificity, utterance length, order) – can be explained by the resource allocation hypothesis (Miller & deWinstanley, 2002): Interaction memory essentially depends on the amount and direction of attention collaborators pay to each other.

Apparatus

Thirty male subjects (undergraduate students from the EPFL) participated in groups of three. Each session lasted about one hour, and was composed of two phases: a discussion phase (Phase 1) and a memory phase (Phase 2). In phase 1 (30 min), participants used a text-based chat tool to discuss about the design of a Learning Center that will soon be built on the EPFL campus. Immediately after the discussion, all participants were asked to answer an on-line questionnaire (20 min). They were presented with a series of messages (primes) automatically selected from their chat. In the experimental condition, participants were asked both to read the prime and to identify its speaker, whereas they were only asked to read the prime in the control condition. All participants had then to retrieve both the speaker and the content of the message (target) that was immediately sent after the prime during the chat session.

The 18 primes presented in Phase 2 were automatically selected from the logfiles produced in Phase 1 according to the following rules. All selected utterances were produced in an *intensive context*. The context for a prime is constituted of four sentences preceding it plus four sentences following it. The context intensity is a superficial indicator of whether participants are highly engaged in the chat or not. We defined a high intensity context as containing relatively long messages that are temporally close and produced by all participants. The chat transcript was divided into three parts. Six primes were chosen from each part of the chat. Among six primes in each part, two primes were chosen for each speaker. Finally, among these two primes, one prime was very specific to its speaker, and one was not specific at all to its speaker. Speaker specificity was calculated as the weighted average standard deviations of verbs and nouns usage by the participants. For instance in the sentence "Libraries help", one noun and one verb are used for the calculation of speaker specificity. Say the verb "help" was used during the chat 10 times by A, 2 times by B and 3 times by C, the standard deviation for this word is 4.36. As the verb was used 15 times overall, the weighted standard deviation is 4.36 / 15 = 0.29. Suppose the noun "library" was used 13 times by A, 12 times by B and 9 times by C, the weighted standard deviation is 2.08 / 34 = 0.06. The speaker specificity for this utterance is the average of weighted standard deviations (0.29 + 0.06) / 2 = 0.175. The rules for choosing prime utterances correspond to 3 variables: the speaker (self versus others), the position (start, middle, end of the chat) as well as the speaker specificity (high versus low). The condition (identification of the prime speaker vs. control) has been also taken into account in our analysis. Due to the many constraints imposed on prime selection, it was often not possible to extract 18 utterances from the chat transcript. In these cases, the memory test was conducted with fewer utterances.

Results and discussion

We examined the effect of our experimental variables on the correctness of both speaker recognition for primes ("who said this?") and speaker recall for targets ("who said the next utterance?"). Predictions for accuracy were computed through logistic regressions. Because participants worked in groups and responded several times to similar questions, we used mixed effect regressions (responses nested in persons nested in groups) to analyse data.

Concerning the prime speaker recognition, a surprising result is found: accuracy in recognizing the speaker of a given utterance is extremely high (77% correct responses overall; 66% correct when the prime is produced by others and 98% correct when the prime is produced by oneself). Moreover, we clearly observe a *generation effect* (H5): participants always recognize their own messages ($\beta_{self} = 3.71$; $p = .000$). There also seems to be an *order effect* (H4) only for primes produced by others: both primacy and recency effects are observed (utterances produced at the beginning, the middle and the end of the chat: 72% correct, 60% correct and 70% correct, respectively). This effect is however not statistically significant ($\beta_{middle} = -0.42$; $p = .29$). We believe that such an effect might appear with a longer delay between the conversation phase and the memory test. Finally, speaker recognition performances tend to be higher for low speaker-specific primes. Although this result is not significant ($\beta_{specificity} = -1.5$; $p = .21$), it contradicts our hypothesis H2 that assumes a positive effect of *speaker specificity* on memory for chat interactions. Possibly our definition of speaker specificity could be enhanced to include signs and expressions (e.g., sms style abbreviations) that were not recognized by the part-of-speech tagger used in automatic analysis of the logfiles.

Concerning target speaker recall, the subject's average performance is weaker but still above the threshold of 1/3 that corresponds to responses by chance since we have three speakers (42% correct responses overall). The *generation effect* (H5) is again observed (50% correct for self-produced targets and 38% correct for targets produced by others); this difference is however marginally significant ($\beta_{self} = 0.47$; $p = .07$). We identified a detrimental effect of the *prime length* (H3) on target speaker recall ($\beta_{wordlength} = -0.058$; $p = .018$): it seems to be easier to recall the speaker of a target when it is preceded by a short rather than a long message in the chat session. This effect suggests a resource allocation problem. Longer is the prime, more cognitive effort is needed to process the prime and less participants in conversation pay attention to the subsequent message. Neither the chat position nor the speaker specificity does significantly affect recall accuracy. Our results also do not support the hypothesis that people use their partners in conversation as retrieval cues (H1). Indeed, asking participants about the prime speaker does not have any effect on target speaker recall. The low number of participants could explain why all these effects did not emerge. Moreover, as Pimentel et al. (2003) said, there is not always a relation between a message and the one that immediately precedes it in a chat session. That could be another reason of the absence of prime effects.

Conclusion

This study deals with a highly important aspect for CSCL, that is, the memorization of chat utterances. The main result is the fact that group members are very good in recognizing who said what. Recall performance is however much weaker when subjects have to remember the speaker of utterances that follow a given prime. This highlights the difficulty for collaborators in remembering and reacting to what their partners state in the chat discussion. Performance is especially weak for target messages preceded by long contributions. We interpret this result as resulting from a resource allocation problem. Our results do not confirm the assumption that partner-specific information could be used as retrieval cues to improve memory because it might be more accessible in memory (Horton & Gerrig, 2005). The results underline the necessity for chat systems to provide users with tools that help them to differentiate their partners' contributions. In future research related to memory for chat interactions, the effect of other variables – for instance, the duration of a chat session or the delay between chat and testing – should be taken into account.

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The integration of synchronous communication across dual interaction spaces

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Abstract: Dual interaction spaces—that combine text chat with a shared graphical work area—have been developed in recent years as CSCL applications to support the synchronous construction and discussion of shared artifacts by distributed small groups of students. However, the simple juxtaposition of the two spaces raises numerous issues for users: How can objects in the shared workspace be referenced from within the chat? How can users track and comprehend all the various simultaneous activities? How can participants coordinate their multifaceted actions? We present three steps toward integration of activities across separate interaction spaces: support for deictic references, implementation of a history feature and display of social awareness information.

Introduction

The construction, modification, annotation and arrangement of shared artifacts are key activities in many collaborative learning settings. Software systems now exist that permit synchronous coordinated manipulation of such shared artifacts even for geographically distributed users, by providing a shared graphical workspace. A shared workspace in a collaborative environment is an area of the software interface that allows a participant to construct and manipulate a graphical object so that the object and the effects of the manipulation appear in the corresponding area of the other participants' interfaces, essentially in real time. These shared workspaces may be used for creating and using external representations of knowledge (Whittaker, 2003), for collaboratively completing design tasks (Reimann & Zumbach, 2001), for working together with simulations (Landsman & Alterman, 2003; Jermann, 2004), or for solving math problems (Stahl, 2007). The design of shared workspaces is an important topic in computer-supported collaborative learning (CSCL).

Learning at a distance requires a medium of communication. The medium can be auditory, audio-visual or text-based. For collaborative learning, textual synchronous communication with chat has two main advantages over audio and even face-to-face: For the chat poster, writing encourages a more careful planning of one's contribution; it fosters reflection on the discourse. For the recipient, the communication is persistent and available in symbolic form that "may be searched, browsed, replayed, annotated, visualized, restructured and recontextualized" (Erickson, 1999).

The combination of a shared workspace with chat makes two regions for interaction available to a group in the form of a dual interaction space (Dillenbourg & Traum, 2006). The chat provides a medium of communication for the exchange of textual messages; the shared workspace allows for the collaborative construction and manipulation of shared artifacts that are relevant to the task at hand. In most groupware systems for synchronous distance learning, the chat and graphical workspace simply appear next to each other as two visually distinct areas of the application that are largely functionally independent of each other. This introduces a number of problems for the users (Suthers, Girardeau & Hundhausen, 2003; van Bruggen, 2003; Pata & Sarapuu, 2003). For instance, if a group of students want to create a concept map in the shared workspace consisting of arguments pro and con and their relationships to each other, this raises the following questions:

1. How can objects and relationships within the workspace be referenced from a posting in the chat area?
2. How can the participants grasp and understand the relationships among each other of the activities and messages that are part of a single collaborative interaction but are distributed across the two interaction spaces? E.g., how can one establish that the message, "I agree," is a response to the introduction of a particular new node in the argumentation graph?
3. How can the participants coordinate their actions in the graphical workspace and in the chat with each other? E.g., when and by whom should an argument introduced in the chat be added to the concept map?

A better software integration of chat and workspace is needed to overcome such difficulties (Dimitracopoulou, 2005; Suthers et al., 2003; McCarthy & Monk, 1994). But from the perspective of a software developer the question, which functionalities must be provided to support the collaboration in dual interaction spaces, is unanswered; the claim for better integration is too general to guide the design of the learning environment. This became apparent in the workshop “Dual interaction spaces” at CSCL 2005 in Taipei organized by Pierre Dillenbourg and the CSCL SIG of Kaleidoscope.

In this paper we propose integration measures for three relevant aspects of the connection of chat and shared workspace:

- deictic referencing,
- coordinating simultaneous activities, and
- understanding of past interactions.

These problems are analyzed in the next section. In a third section we will describe the integration measures. Then in a section on experiences with ConcertChat, a collaboration environment that implements these measures will be presented, before we conclude with questions for future work.

For the sake of simplicity this papers describes our development of the integration measures as a linear process starting with problem analysis that leads to certain functionalities. As we know from CSCL research, this idealized development seldom holds. Our system was developed during the last 5 years. We started with assumptions of what is needed by the users, developed first prototypes and used them in serious learning settings. The analysis of those real collaborations provided us insights into the complex nature of mediated collaborative meaning making in dual interaction spaces. Our focus gradually shifted from an individual point of view (what is needed by a user) to a group cognition (Stahl, 2006) perspective taking into account the creative, simultaneous, interwoven interactions among the team members.

Problems in combined interaction spaces

A shared workspace can play at least two contrasting roles within a collaborative session. It can, for instance, provide the central location for the joint activity of the participants, with the chat playing a supportive role in discussing and disambiguating the activities that take place in the workspace. Conversely, the chat discourse can dominate, with the graphical workspace serving as a resource for clarification or for illustrating things that are hard to articulate in words. Which way communication is divided between the dual spaces depends upon the current task, the meta-communicative skills of the participants and the respective affordances of the two media (Pata & Sarapuu, 2003; Dillenbourg & Traum, 2006). The activities in the chat and the shared workspace are typically intimately interrelated. To the extent that the technology supports it, participants may coordinate their use of the dual spaces in creative and subtle ways (see e.g., Stahl et al 2006).

A prominent characteristic of chat is the delay between the production of a message by its author and its presentation to others when it is complete. This has two main advantages: that the author can revise the message before sending it (Clark & Brennan, 1991) and that several people can be producing messages at the same time, unlike in spoken conversation. However, it also leads to the constant danger of sequential incoherence, which forces the participants to work additionally on explicitly coordinating the content and structure of their interactions. The problem is that, unlike in conversation, in chat the appearance of responses often do not immediately temporally follow the messages to which they are responding. The coherence of interaction is highly dependent upon the response structure between messages. But in the time it takes for someone to prepare and send a response to one note, a note from someone else can be posted, causing “interrupted turn adjacency” (Herring, 1999). A number of specific communication strategies may be evoked to deal with this (Fuks, Pimentel, & de Lucena, 2006; Lonchamp, 2006; Murray, 2000). In order to minimize the delay in responding, mistakes in syntax and wording are accepted and many abbreviations or acronyms are used (Garcia & Jacobs, 1999). Cohesive devices like explicitly naming the addressee of a contribution (Nash, 2005) are used to make references explicit.

The fact that several people can be producing messages at the same time means that the common conversational rules of turn-taking do not apply (Sacks, Schegloff, & Jefferson, 1974). The resulting parallelism can scarcely be avoided, and must particularly be taken into account when multiple topics are discussed simultaneously (1). This problem is eased by the fact that the flow of chat is documented in the persistent transcript, which is visible—at least for the last several postings. The chat window serves not only as the location of communications, but also as a representation of the temporal order of the messages. In contrast, the graphical workspace usually only shows the current state. All information about the actions and actors who brought about this state is ephemeral.

These problems resulting from the visual and functional juxtaposition of chat and workspace have the consequence that it is hard for users to track and specify relations of content and sequentiality between the textual contributions and the graphical activities. Specifically, there are three major problems:

- *Deictic references.* An important means of communicative expression during collaboration with shared workspaces is deixis (Barnard, May & Salber, 1996; Clark & Wilkes-Gibbs, 1986)—the referencing of objects, relations and actions in the shared visual environment. When chat is used as the communication medium, deictic referencing is associated with high production costs and potentially also higher levels of ambiguity because gestural pointing is not possible. Purely textual descriptions of the object or of its specific position are obvious solutions, but there is no guarantee that such a description will be intelligible to others when they receive it because another user of the shared workspace may have moved or even deleted the object in the meantime.
- *Decontextualization of actions and messages.* When collaborating in a dual interaction space, participants interact with each other through chat messages and modifications to artifacts in the workspace. Whereas the persistent chat history represents the complete sequentiality of the discursive contributions, the same does not hold for the workspace. Both the ordering and the intermediate results of actions in the shared workspace are fleeting. This has two direct consequences. First, the necessary context for interpreting messages that reference artifacts in the workspace can quickly disappear. This defeats the important advantage of the persistent discourse history, which can support retrospective reflection. Second, the phenomenon of interrupted turn adjacency, described above, is heightened. During the time it takes for one person to respond, others can not only insert new messages but also modify referenced graphical artifacts.
- *The coordination of communication and interaction.* In a dual interaction space, different participants can simultaneously be typing and posting chat messages or producing objects in the workspace. In collaboration, these various activities are interrelated: a message can announce or comment upon an action in the shared workspace and a workspace action can respond to or clarify a chat message. The awareness of the activities of the other people is a prerequisite for the construction of common ground (Dillenbourg & Traum, 2006). In chat, the chat history documents the sequence of discursive activities of the participants and the usual system messages when someone enters of leaves the room provide basic information about who is present. A series of interface features have been established to support coordination in shared workspaces (Gutwin & Greenberg, 2002), helping with turn taking and the anticipation of actions by other participants. For instance, objects that were just selected by users might be color-coded to indicate who is using them and the location of the user's mouse can be indicated (Stefik, Bobrow, Foster, Lanning & Tatar, 1987). Similarly, many chat systems display a message near the chat input area if someone is typing. However, if all these awareness techniques are combined in an environment with dual interactions spaces, then they can overwhelm the limited attentional abilities of humans. The fleeting awareness messages scattered across the interface require users to pay constant attention to their whole screen.

Support through integration

People collaborating in a dual interaction space are exposed to a series of problems that derive from the visually and functionally separated nature of the chat and workspace components. Three software mechanisms will now be presented that integrate these components with each other:

1. An explicit referencing tool that makes possible deictic references from the chat to the workspace.
2. An integrated history function that documents the on-going collaboration process consisting of the activities in the chat and in the shared workspace, and lets users review it.
3. A visually integrated social awareness display that supports the perception of the simultaneous activities of the multiple participants in both areas.

To illustrate these integration measures, a shared whiteboard will be described as a common workspace for the collaborative creation of drawings, concept graphs and mind maps. See Figure 1 for an example showing the most important interface elements.

Mechanism 1: Explicit References

The concept of explicit references (2) addresses the difficulty of deictic referencing in the textual medium of chat. Pointing gestures are frequently used in face-to-face conversation (Bekker, Olson & Olson, 1995), for instance to identify objects and to clarify relationships among objects. Similarly, *explicit references* in chat allow one to associate a chat contribution with objects in the shared workspace and with other chat messages using graphical connectors. A graphical reference to a chat message can point to the whole message, a single word or some portion of the message. A reference can also point to an object or a region in the workspace. In the simplest case, one might want to point to a particular object, but in other situations to just a specific part of the object or else to a spatial constellation of several objects. So a number of different forms of referencing must be supported.

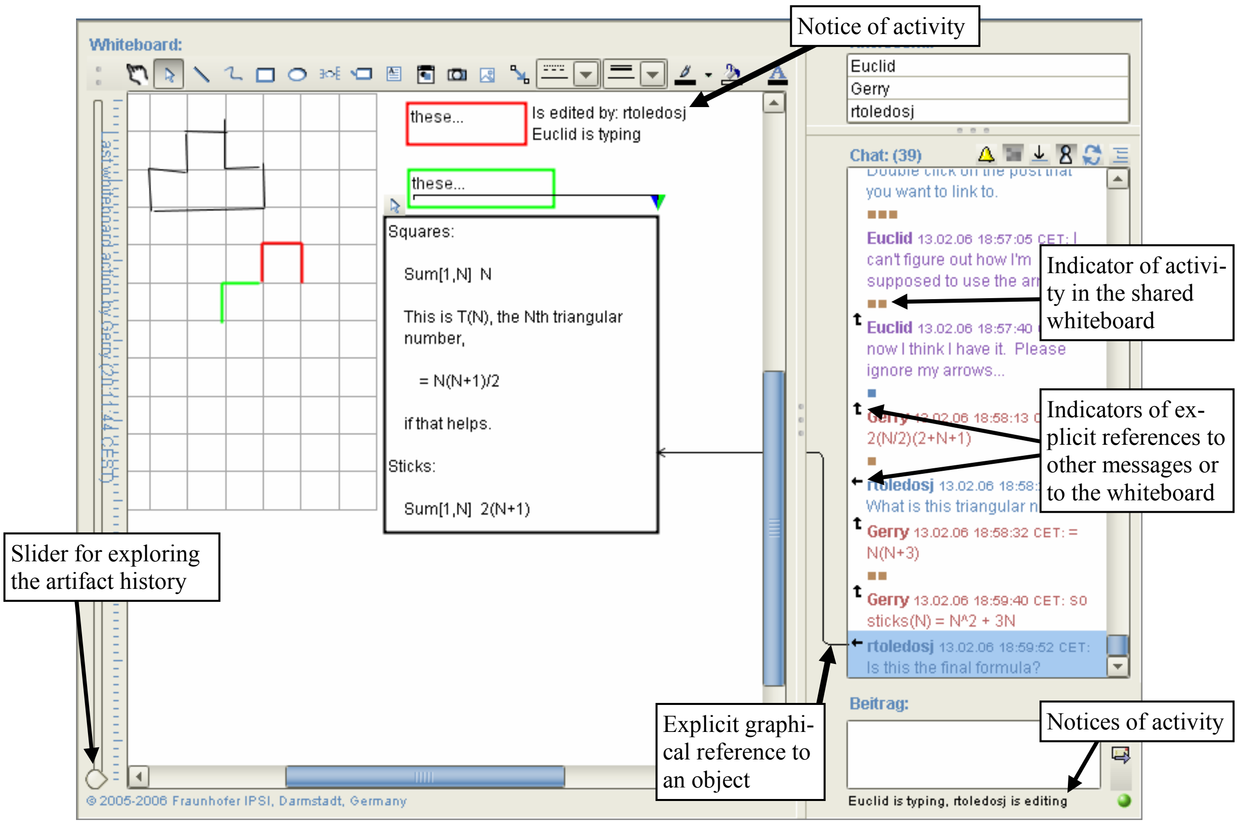

Figure 1. This screenshot shows the state of the ConcertChat interface after the posting of a message with an explicit reference to a textbox in the shared workspace. Rtoledosj is currently working on the large textbox while Euclid is typing a chat message. The interface features for showing explicit references, the workspace history and awareness messages have been annotated.

For summary statements in the chat—e.g., "These two arguments contradict each other"—multiple references can be made to relevant messages and objects. Just as with gestural pointing, the effective meaning of a graphical reference is given only once both the gestural and verbal messages are given. Thus, a reference can be used to clarify a "response-to-that-message" relation as well as to indicate a "related-to-this-object" relation.

The usability of an explicit referencing tool depends upon its effect on the media-dependent costs of production and reception (Clark & Brennan, 1991). In order to keep these costs low, appropriate interaction possibilities must be available for the easy production of references and for the visualization of references.

In order to maintain the chronological order of the chat history—rather than threading it—with the associated advantages for retroactive reflection, a reference is represented by a graphical arrow going from the referencing chat message to the referenced object or message. As soon as the referencing message is displayed, the accompanying reference arrow is also displayed, as illustrated in Figure 1.

Mechanism 2: Artifact history

In collaboration in dual interaction spaces, the actions in the shared workspace and the messages in the chat are but two facets of a single activity. While the chat displays a persistent history of the collaborative discourse, there is no corresponding history display for the workspace, let alone an integrated history for the whole collaboration. In technical terms, an *artifact history* of the objects in the workspace is a chronological collection of the various different versions or circumstances of the workspace resulting from the manipulations of the participants. In a shared whiteboard, every creation, movement and editing of an object changes the state of the workspace (3). The provision of an artifact history has two goals: to preserve the workspace context at various times and to represent its evolutionary process. The context of the workspace at the time when a chat message was being produced is important to know in order to interpret the message–particularly if the message explicitly references artifacts in the workspace. The artifact history permits the reconstruction of that context and encodes that context in the software representation of the reference. As needed, the historical context corresponding to a message of interest can be reconstructed and displayed. The other goal is to allow the normally fleeting artifact history to be replayed. The chronologically ordered developmental steps can be played back like the frames of a film, making possible reflection on the whole collaborative construction. Reflection in the group discussion is facilitated by the combination of being able to review the past developmental stages of the shared workspace and being able to point to a particular stage with an explicit reference.

Mechanism 3: Integrated activity awareness

The *integration of activity displays* has the goal of making it easier to be aware of the simultaneous activity of the other participants. Awareness of these activities is a prerequisite for constructing and maintaining a mutual understanding of the chat messages and the changes to the graphical artifacts—and therefore provides a necessary foundation for collaboration. In a chat environment, the chat history documents all the activities—both the individual messages and information about participant presence. This chronological documentation of activity suggests that it could serve as a representation of all activity within a dual interaction space as well.

With chat, the process of producing a message is not directly perceivable by the other participants. The extent to which a long lasting and cognitively strenuous activity in a shared workspace is observable for the other participants depends upon the nature of the workspace and the granularity of the operations that are displayed for everyone. For instance, the editing of a textbox annotation in the shared workspace may only become visible for the others when the edit is completed. Activity awareness notifications have been established to support the coordination of activities like joint editing, so someone knows not to try to edit an object that someone else is currently editing. In a dual interaction space, however, it is necessary to visually integrate these notices that are associated with the locations of different individual activities. If one participant wants to post a chat message in response to a contribution from another (such as responding to an annotation in the shared workspace with: “I would say that differently”), then she might hold off doing this if she is informed that he has just begun to make a change in the workspace that might very well serve to clarify his original contribution. Conversely, if he is informed that she is typing a chat message, he may delay his change in anticipation of a new objection. Both cases of course presume that the information about the activities is perceived. This can be supported by displaying the awareness information at the appropriate location (see Figure 1).

Integrated dual interaction spaces in use

The described integration measures are implemented in a system called ConcertChat (4). It was developed during the last 5 years. Since 2004, the Virtual Math Teams Project (5) has been using a collaboration environment based on ConcertChat for the discussion and solution of mathematical problems by small groups of students. A detailed case study of how deictic referencing was conducted in this context using the ConcertChat functionality in the dual interaction space is presented by Stahl et al. (2006). Further studies of the use of ConcertChat’s explicit referencing tool are reported by Mühlpfordt & Wessner (2005). These provide some evidence that the participants were able to employ effective communication strategies with the help of the explicit referencing.

For researchers, the persistence of all activities in a dual interaction space provides the possibility of conducting fine-grained analyses of group interaction, as illustrated by Stahl et al. (2006). To support this, a replay version of ConcertChat has been developed that allows all the activities to be repeatedly reviewed, with the chat and workspace histories precisely coordinated. As mentioned in the introduction, the in-depth analysis of collaborative meaning making of groups learning together in the ConcertChat environment provided us insights in how the functionalities are used. The next three examples illustrate that.

All examples are taken from Spring Fest 2006 of the Virtual Math Teams (VMT) service at http://mathforum.org. The collaborative context was set by organizing a contest: members of the most collaborative teams would win prizes. Students were recruited globally through teachers who were involved in other Math Forum activities. The teams in the excerpts consisted of students from Singapore (example 1) and from the US (example 2 and 3), as well as a facilitator from the Math Forum, who provided technical assistance. At the beginning of the first sessions the facilitators briefly explained the functionalities of the learning environment to the groups. Pedagogically, the topic for discussion was an open-ended exploration of geometric patterns. An initial pattern of squares formed from sticks was given. The students were to figure out the formulae for the number of squares and the number of sticks at stage N first, and then explore other patterns that they or other teams invented.

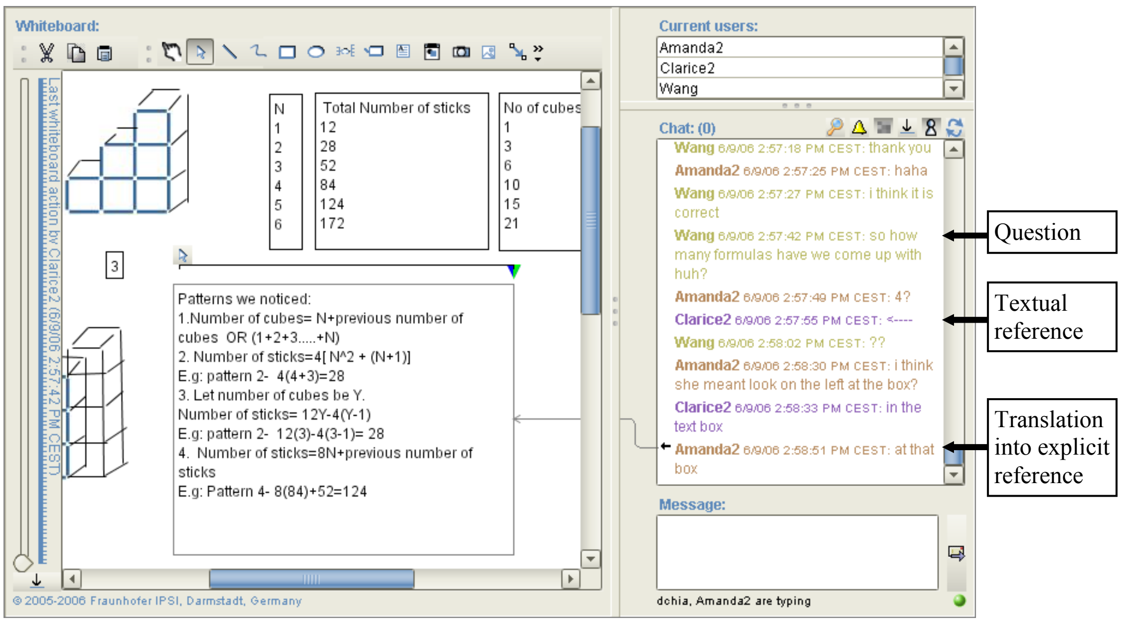

Figure 2. Explicit referencing must be learned. Clarice2 "imitates" an explicit reference to a textbox ("<----"), and Amanda2 is actually doing it.

Example 1 illustrates how the referencing tool is established by the group to ease deictic references. Figure 2 shows a screen shot of a VMT session with 4 participants, Amanda2, Clarice2, Wang, and Dshia. In that situation the group reflects on what aspects of the mathematical problem at hand they already solved. Wang asks "so how many formulas have we come up with huh?" and both Amanda2 and Clarice2 respond in the subsequent messages. Here the interesting response is from Clarice2: "<----". With that she textually simulates an explicit reference. In contrast to other group members Clarice2 has never used the referencing tool before, so it might be that she does not know how to create one. Wang's reply with two question marks ("??") indicates a lack of understanding. Also Amanda2, while providing an interpretation ("I think she meant look on the left at the text box?"), closes the message with a question mark. With her subsequent message ("in the text box") Clarice2 again tries to establish a reference to the textbox on the shared whiteboard. Amanda2 finally translates this into a posting with an explicit reference to the textbox with all the collected formulas.

While Clarice2 is a novice in using the referencing tool, Bwang8—in a second example—uses it creatively to incorporate a formula written on the shared whiteboard into his explanation of a derived formula (see Figure 3) for the number of white squares in the rectangular pattern on the left. In a first step he refers to an already found formula for the number of squares in one corner ("we can use the equation from session 1" and "n(n+1)/2"). Then in a second step he extends that to the number of squares in all four corners. This number must be subtracted from the number of all squares in the pattern. The group already found a formula for the latter number and documented that in a textbox on the whiteboard ("big square: (2n-1)/2"). Bwang8's posting of the final formula (number 4 in Figure 3) is linked to that box. In that case the referencing tool is used not merely for a deictic reference, but for incorporating an intermediate step in his formula derivation (6).

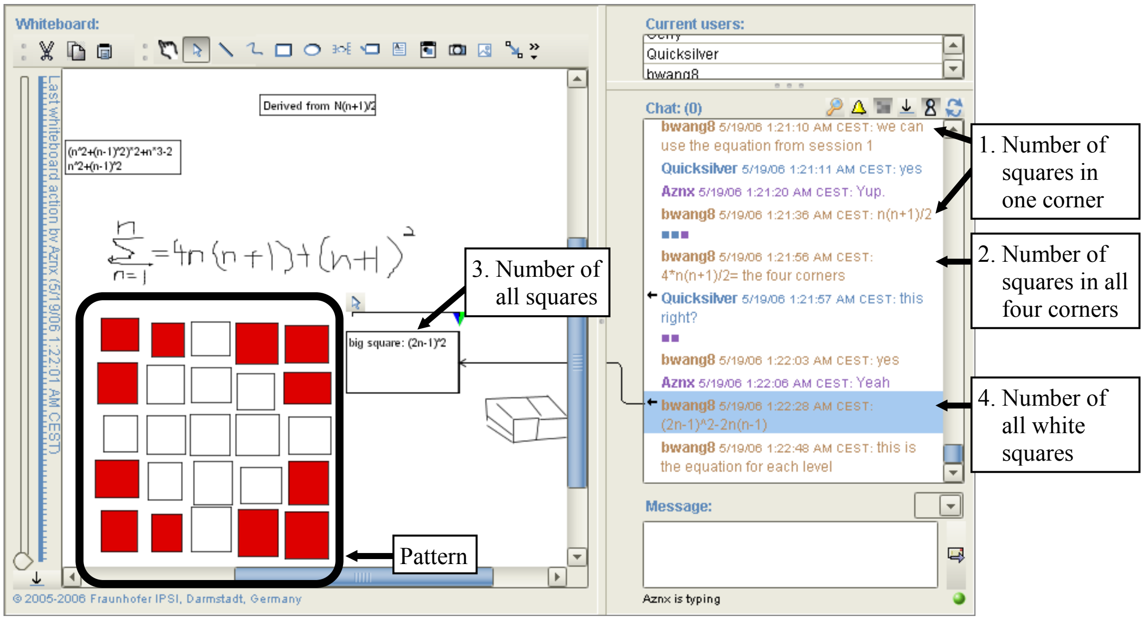

Figure 3. Bwang8 uses an explicit reference to integrate an element of the whiteboard in his/her argumentation.

The third example is from the same group (see Table 1 for the excerpt of the chat log) and shows that for the groups it is sometimes not trivial to choose the appropriate interaction space. In line 1516 Aznx invites the others to "simplify their formula" (he is actually referring to a formula published by another group) and after Bwang8's request ("how did you simplify it", line 1525) he posts 5 chat messages describing the transformation of the formula. But his team members Quicksilver and Bwang8 seem not to understand that ("im lost", line 1533). Aznx now switches to the whiteboard ("I'll do it on the board", line 1536) and uses it for writing down the derivation. Figure 4 shows a screen shot of his final drawings. It also shows that Aznx's drawings (each drawing step is indicated by a small square in the chat history on the right side) are interwoven with chat postings, even from himself (line 1542). The interactions of the group are distributed over both interaction spaces, but highly interrelated. In line 1546 ("whyd u multiply by the two") we can see, how the referencing tool is used by Quicksilver for establishing referential identity.

Table 1: A seven minute excerpt of the chat log. Line numbers have been added.

line	time	participant	chat posting
1516	07.43.36	Aznx	simplify their formula
1517	07.43.51	Quicksilver	k
1518	07.43.55	bwang8	what do you mean
1519	07.44.30	Aznx	2(n^2+n^2-2n+1)+3n-2
1520	07.44.34	bwang8	i don't see how you can simplify it
1521	07.44.35	Aznx	simply the formula
1522	07.44.40	Aznx	for the number of sticks
1523	07.44.45	Aznx	so that simplifies to...
1524	07.45.45	Aznx	I stil get the same.
1525	07.46.20	bwang8	how did you simplify it
1526	07.46.27	Aznx	um
1527	07.46.32	Aznx	square the n-1
1528	07.46.39	Aznx	then multiply the whole thing by 2
1529	07.46.47	Aznx	then multiply the 3 and n
1530	07.46.51	Aznx	and add it with that
1531	07.46.57	Aznx	and subtract by 2

line	time	participant	chat posting
1532	07.47.14	bwang8	quicksliver
1533	07.47.19	Quicksilver	im lost
1534	07.47.23	bwang8	did you get the same answer
1535	07.47.30	Quicksilver	no
1536	07.47.39	Aznx	i'll do it on the board
		Aznx starts drawing on the whiteboard	
1537	07.47.44	Quicksilver	yeah
1538	07.47.53	Quicksilver	i got something totally difrent
1539	07.48.36	bwang8	so far i got $4*n^2+3*n$
1540	07.48.55	Quicksilver	indranil rite in the box
1541	07.49.17	bwang8	i mean 4n^2-n
1542	07.49.26	Aznx	EXactly
1543	07.49.40	Quicksilver	yea that waht azn x got eralier
1544	07.50.00	bwang8	holy
1545	07.50.03	bwang8	moley
1546	07.50.05	Quicksilver	whyd u multiply by the two

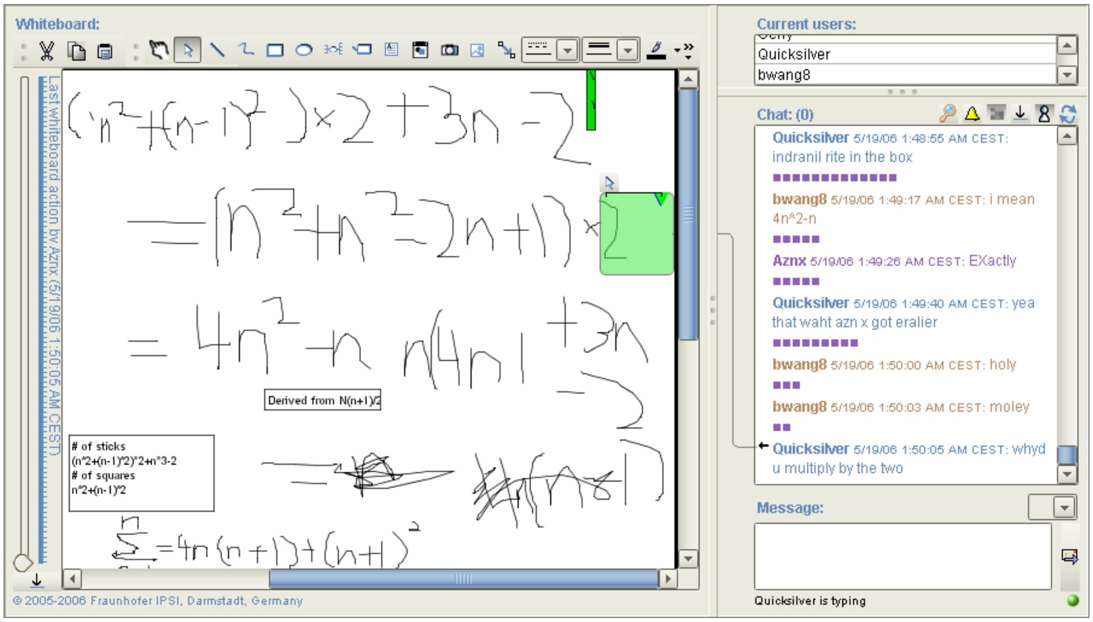

Figure 4. Screen shot of the ConcertChat environment after receiving message 1546 of table 1.

Conclusions and future work

The design of dual interaction spaces for synchronous collaborative learning has to take into account the dynamic, tightly coupled and interwoven nature of the activities that are scattered across both media: the chat and the shared workspace. This demands a) support for deictic referencing, b) the as access to an integrated history and c) integrated activity awareness. We exemplified the advantages offered by such integration measures.

Software developers like to think in modules, but when combining a shared workspace with a chat into one collaboration environment we have to think holistically about using that workspace in the context of a chat conversation and chatting in the context of working together in the workspace.

The experiences with ConcertChat to date suggest a series of further research questions:

1. The storing of explicit references and the integrated representation of all activities make available additional structural and temporal information about the collaborative artifacts in the two interaction spaces. To what extent is it possible to use this information to construct a retrospective indexing, documentation or summarization of the collaboration that would facilitate future reflection or recall by the participants—for instance, when they return to the room for a subsequent session?
2. An essential difference between a chat window and a shared whiteboard is the persistence of the artifacts (Dillenbourg & Traum, 2006). While a textbox in a shared whiteboard remains visible indefinitely (unless it is edited or deleted by a participant), the same is not true for chat contributions; they scroll out of sight with the appearance of the following discourse. Interesting questions arise when the additional possibility of audio communication offers a non-persistent medium. Can this supplementary mode of communication be substituted for chat to the advantage of the participants or will it be used as a secondary addition? What different communication strategies would result?
3. How can the concepts of explicit referencing, integrated activity awareness, and artifact history be applied to multiple interaction spaces, in which the collaboration environment provides even more than two primary workspaces?

Endnotes

(1) Despite the fact that this documentation is characterized by sequential incoherence, participants can apparently read and understand the chats amazingly well (Herring, 1999).

(2) The presentation of the concept of explicit referencing here is an expansion of the discussion by Pfister & Mühlpfordt (2002).

(3) The granularity of the operations depends of the kind of shared workspace. Imagine, for instance the use of a wiki page as a shared material (Haake, Schümmer, Bourimi, Landgraf & Haake, 2004). Then the artifact history would be defined by the various versions of the page.
(4) ConcertChat can be accessed online at: http://chat.ipsi.fraunhofer.de. The project is open source with a BSD-like license and can be downloaded at: http://sourceforge.net/projects/concertchat/.
(5) The Virtual Math Teams project is available online at: http://mathforum.org/vmt.
(6) In that step Bwang8 also implicitly transforms the different usages of the variable "n": whereas the formula for the corners started with level 0, the formula for the overall number of squares started with level 1.

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Acknowledgments

ConcertChat was developed during the last 5 years in a collaborative project at the Fraunhofer Institute IPSI in Darmstadt, Germany. Involved in the development were among others Axel Guicking, Torsten Holmer, Friederike Jödick, Martin Mühlpfordt, Christian Stab, Martin Wessner, Bo Xiao. The Virtual Math Teams Project is a collaborative effort at Drexel University. The Principal Investigators are Gerry Stahl, Stephen Weimar and Wesley Shumar. A number of Math Forum staff work on the project, especially Annie Fetter and Ian Underwood. The graduate research assistants are Murat Cakir, Johann Sarmiento, Ramon Toledo and Nan Zhou. Alan Zemel was a post-doc. The following visiting researchers have spent 3 to 6 months on the project: Jan-Willem Strijbos (Netherlands), Fatos Xhafa (Spain), Stefan Trausan-Matu (Romania), Martin Wessner (Germany), Elizabeth Charles (Canada), Martin Mühlpfordt (Germany) and Weiqin Chen (Norway and China). The VMT project is supported by grants from the NSDL, IERI and SLC programs of the US National Science Foundation.

Effects of synchronous and asynchronous CMC on interactive argumentation

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Abstract: This study examined how different types of computer-mediated communication (CMC) influences the way pre-university students argue about genetically modified organisms. A total of 39 dyads discussed the topic using either synchronous (chat) or asynchronous (discussion board) CMC, after which they collaboratively wrote an argumentative text in a synchronous groupware environment. It was hypothesized that synchronous CMC would stimulate deep argumentation because of feedback immediacy while asynchronous CMC would stimulate gathering arguments because it allows increased reflection time. Finally, the study sought to determine if students who argue well during a discussion also wrote better argumentative texts. The results obtained partly confirmed the expectations. Students using synchronous CMC argue in a more elaborated way than students using asynchronous CMC. However, in contrast to the hypothesis, students using asynchronous CMC produced more accurate argumentative texts. This study sheds light on how synchronous and asynchronous CMC will be suitable for specific collaborative learning processes.

Introduction

Computer-mediated communication (CMC) is undoubtedly an important part of everyday life for many preadolescents and adolescents. Valkenburg and Peter (2006) found that 88% of Dutch adolescents aged 12 to 16 years use online communication - mainly Instant Messaging - with friends. CMC is fast becoming an increasingly common means of communication in everyday life, and parallel to this there is also an observable increase in use of CMC in education, especially in the field of computer-supported collaborative learning (CSCL). This approach to online collaboration seems to justify using CMC as cognitive tool to facilitate and promote collaborative knowledge building (Lehtinen, Hakkarinen, Lipponen, Rahikainen, & Muukkonen, 1999). However, CMC is a very broad term and comprises many types of communication including chat rooms, MOOs, Instant Messaging, videoconferencing, e-mail, and discussion boards.

There are many approaches to CMC where both the success and the failure of interactions in CSCL are explained by the same characteristics. For example, some researchers explain unequal student participation during CSCL by the lack of non-verbal cues in CMC which causes depersonalisation of the communication (Kreijns, 2004). On the other hand the lack of non-verbal cues is thought to stimulate elaboration and force students to explicate their thoughts, leading to positive learning outcomes (Veldhuis-Diermanse, 2002). The choice of justification depends on the perspective taken on whether CMC stimulates or constrains collaborative learning processes (McAteer, Tolmie, Duffy, & Corbett, 1997). Two issues are very important here. First, it is important to distinguish between different CMC technologies and their specific affordances and constraints. A major distinction can, for example, be made between synchronous and asynchronous CMC. Synchronous CMC occurs in real time and requires simultaneous participation while asynchronous CMC does not occur in real time and participants can communicate whenever they choose. Differences between asynchronous and synchronous CMC can account for different effects on collaborative learning such as differences in reflection on the content and coherency of the communication. Second, it is important to distinguish between different goals and characteristics of the learning context in which CMC is used. Branon and Essex (2001) show that educators have clear ideas about the appropriate fit between learning tasks and CMC technologies. Asynchronous communication was reported to encourage in-depth discussion in which all students had equal chances to participate. Synchronous communication was seen by the educators to facilitate quick problem-solving, brainstorming, and creating a sense of presence which is absent in asynchronous communication. Also, several researchers in the field of CSCL and communication research conclude that asynchronous systems should be preferred when the goal is critical thinking and deep learning (e.g., McGrath & Hollingshead, 1993).

However, despite the assumed lack of fit between synchronous communication and ‘deep learning’ tasks involving negotiation, argumentation, and complex problem solving, much CSCL research aimed at promoting reflective discussion is carried out with chat tools (e.g., Baker & Lund, 1997; Veerman, Andriessen, Kanselaar, 2002; Walker, 2004). This raises the question as to whether using synchronous CMC for deep learning tasks is really ineffective when compared to asynchronous CMC. This contribution tries to answer the question of whether synchronous CMC, compared to asynchronous CMC, has characteristics that create opportunities for collaborative learning processes such as discussion and negotiation.

Discussion with CMC – Interactive Argumentation

Chinn and Anderson (1998) describe the ideal collaborative learning situation as a conversation between participants in which there is a collective searching for different positions, reasons, and evidence in an infinite space of debate. They call this *interactive argumentation.* The aim of interactive argumentation is not to establish truth or win an argument, but rather to explore an issue at stake. Nussbaum (2003) defines this as a co-constructive style of argumentation. Munneke, Andriessen, Kanselaar, and Kirschner (2007) present different opportunities for coupling interactive argumentation and learning. A first learning opportunity is justifying claims which can promote cognitive learning processes such as self-explanation and elaboration (Baker, 2003). A second opportunity is giving counter arguments which stimulates knowledge building since participants must both examine their own views and initial arguments as well as negotiate with each other about the meaning of concepts and information (Leitão, 2000). Students, while arguing about a topic, can then reach a broader and deeper understanding of the topic (Munneke et al.;Van Amelsvoort, 2006). Broadening deals with gathering information from different points of view, and with assembling different subtopics and associated arguments, while deepening deals with different points of view, using evidence, counterarguments and rebuttals, and achieving convergence on different pieces of information.

But what are the effects of synchronous and asynchronous CMC on the discourse of interactive argumentation? There is little research that has attempted to compare different modes of communication during interactive argumentation. Veerman (2000) compared the results of different experimental studies and concluded that discussions mediated by synchronous CMC contained more rebuttals and counterarguments and included more social talk than discussion that was mediated by asynchronous CMC. There was more indirect argumentation in asynchronous CMC, students were more critical of evidence there, and the discussion contained more constructive activities such as adding, explaining, evaluating, summarizing, or transforming information. Her explanation for these differences lies mainly in the temporality of asynchronous CMC which give students opportunities to take time for reflection. However, Veerman compared different studies with different learning goals, contexts, and topics. The question arises whether her results hold for other situations in which asynchronous and synchronous CMC are used for argumentation.

Approaches to CMC

A classical approach to the effects of media on communication is social presence theory (Short, Williams, & Christie, 1976), which laid the groundwork for subsequent theories such as media richness theory (Daft & Lengel, cited in Carlson & Zmud, 1999). Media richness refers to a medium’s ability to communicate information in such a way that message uncertainty or equivocality is minimized (i.e., the task or topic under discussion is unambiguous). The richness of a medium is based on: (1) immediacy of feedback, (2) transmission of multiple cues such as non-verbal signals and voice tone, (3) use of natural language, and (4) conveyance of personal emotions. Based upon these criteria, face-to-face communication is richest due to the availability of immediate feedback and the use of multiple cues. CMC is a ‘lean’ medium because of its lack of non-verbal signals and quick responses which lead to a depersonalization effect. Media richness theory argues that difficult tasks with a high level of uncertainty and equivocality do not fit lean media like CMC because of this depersonalization (Carlson & Zmud; Walther, 1995).

However, this theory has been criticized on the grounds of its technology-driven approach (Tanis, 2003). Fulk (1993), for example, argues that the effects of information and communication technologies (ICTs) are determined by the interaction between users, technology, and context and not solely by media characteristics. In this context Carlson and Zmud (1999) and Walther (1995) accentuate the importance of the amount of experience a user has had with CMC, the sort of task to be accomplished, and the time users may need to communicate effectively via CMC. Along with this, Herring (1999) argues that despite a lack of immediate feedback and incoherent interactions many users are attracted by CMC because its features enable different kinds of interactions than does face-to-face conversation. Grounding theory (Clark & Brennan, 1991) takes the CMC user into account, arguing that people can effectively communicate using various types of media because they always seek to establish and maintain common ground. The principle of 'least effort required to ground communication' determines how users deal with the different grounding costs of CMC which makes not all media fit for all types of tasks (Honeycutt, 2001).

Another approach that takes task types into account is media synchronicity theory (Dennis & Valacich, 1999) which was developed because of the aforementioned criticism of media richness theory. Synchronicity theory argues that all tasks are composed of the communication processes *conveyance* (i.e.,information exchange) and *convergence* (i.e., establishing meaning for each piece of information). Conveyance and convergence need different characteristics of communication media. Dennis and Valacich identify five media dimensions that can affect how users of media interact with each other, namely feedback immediacy, symbol variety, parallelism, rehearsability, and reprocessability. Feedback immediacy is the speed of communication and the extent to which users can give rapid feedback on the messages received. Symbol variety refers to the number of ways information can be communicated, such as via verbal and nonverbal cues. Parallelism is about the number of simultaneous conversations that can exist effectively in the same medium. Rehearsability refers to the users' ability to rehearse a message before the actual communication. Finally, reprocessability refers to the ability to review and analyze sent messages more than once at different points of time. According to Dennis and Valacich, convergence processes need high synchronicity which entails high feedback immediacy and low parallelism while conveyance processes need low synchronicity entailing low feedback immediacy and high parallelism. Rehearsability, symbol variety, and reprocessability are seen as dimensions which handle the equivocality of a task. When a message is complex and equivocal it is important to have time to reflect and to reprocess a message, lowering the synchronicity of a medium because a highly rehearsable medium, for example, tends to allow less feedback.

Research Questions

This contribution reports on research investigating the effects synchronous and asynchronous CMC on interactive argumentation in student dyads discussing a complex problem. The theoretical introduction shows that different ideas about the effects of CMC on communication between people coexist and that there is little research on CMC's effect on specific processes such as interactive argumentation. Veerman (2002) indicated that asynchronous CMC, when compared to synchronous CMC, is best for students engaged in a critical discussion because of the reflection time that asynchronous CMC allows. However, based upon media synchronicity theory (Dennis & Valacich, 1999), asynchronous CMC is less advantageous for processes such as negotiation of meaning (i.e., convergence) because of its lack of feedback immediacy while more advantageous when students must exchange different pieces of information (i.e., conveyance). Translating this to interactive argumentation, this means that synchronous CMC should stimulate a deepening the space of debate (i.e., elaborating different points of view, using evidence, counterarguments, and rebuttals) while asynchronous CMC should stimulate broadening the space of debate (i.e., gathering information from different points of view). In this line of reasoning, the research questions here are: (1) What is the effect of synchronous and asynchronous CMC on broadening the space of debate? and (2) What is the effect of synchronous and asynchronous CMC on deepening the space of debate? It is hypothesized that using synchronous CMC will result in fewer, but longer sequences of argumentation compared to asynchronous CMC. Comparing synchronous and asynchronous communication is a methodologically complex issue because the amount of time students are communicating and what is happening between sessions may considerably differ between conditions. To this end, a third research question tries to establish what effect synchronous or asynchronous discussion has on how students perform on a subsequent writing task. It is thought that optimal support for students for convergence processes during the discussion phase will help them write argumentative texts with more accurate argumentation during a subsequent writing phase.

Method

Participants

Subjects in this study were 104 pre-university students aged 15-17 ($M = 16.1$, $SD = 0.72$) from two academic high schools in the Netherlands. The schools were situated in the same geographic area and were demographically comparable, including student socioeconomic background. Because of this comparability, each school was assigned to one of two treatment groups instead of carrying out the different treatments in both schools. This study was carried out in seven parallel groups taught by six different teachers. The teachers collaborated with the research team on the development of the argumentative task. Students worked on the task for three weeks, during classes planned for Dutch language or at home, in their own time, depending on the experimental condition.

Design

A posttest-only, quasi-experimental design with two treatment groups was used to compare argumentation in two different CMC situations. Students in one condition discussed the topic of genetically modified organisms (GMOs) with the help of synchronous CMC, while students in the other condition discussed the topic through asynchronous CMC. Due to organisational limitations, it was not possible to randomly divide the students and one school was assigned to the synchronous CMC condition and the other to the asynchronous CMC condition. The students collaborated in randomly composed dyads, heterogeneous with respect to gender. To avoid student dyads that would have problems getting along (the students knew each other and had a collective social history), teachers were requested to check the dyads with respect to compatibility. Eighteen dyads (10 synchronous, 8 asynchronous) were excluded from analyses because they missed more than one lessons or because they posted less than three substantial messages in the asynchronous condition. For analysis, 20 dyads remained in the synchronous condition and 19 in the asynchronous condition.

Task and Materials

Dyads worked on an argumentative collaborative task in two phases, namely a discussion phase and a writing phase. These phases were preceded by an introduction to the task in the class and a period of individual preparation. The difference between the two conditions was created during the discussion phase. During preparation, students were introduced to the subject of GMOs in the class and instructed about what argumentation entailed. After this, students received an individual take-home assignment which took approximately 40 minutes to carry out. They had to read eight popular, easy-to-read sources on the topic of GMOs. The discussion phase in the *synchronous* condition consisted of two 45-minute meetings where students were asked to discuss GMOs using the chat facility in TC3 (Text Composer, Computer-supported, and Collaborative; see Figure 1; Jaspers & Erkens, 2002).

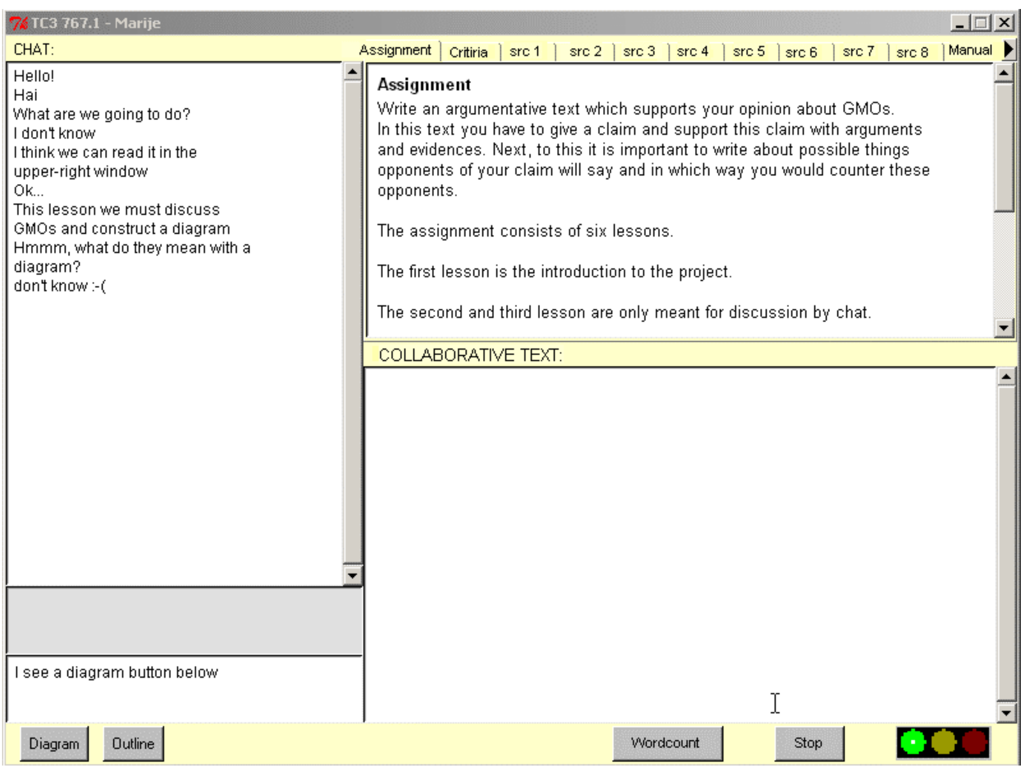

Figure 1. Screenshot of TC3.

In the *asynchronous* condition, in which each student was asked to post six substantial messages in Blackboard® (see Figure 2), the discussion phase lasted two weeks. A substantial message was defined as a message consisting of at least one argument. Students had to post their messages (i.e., work asynchronously) in their own time. There was one class meeting to help students if they were having a problem with the task and did not post enough messages. The writing phase was equivalent for both conditions. All dyads wrote an argumentative text about GMOs using TC3 and the students communicated synchronously within the dyad via TC3's chat facility. This writing phase encompassed three lessons (approximately 120 minutes).

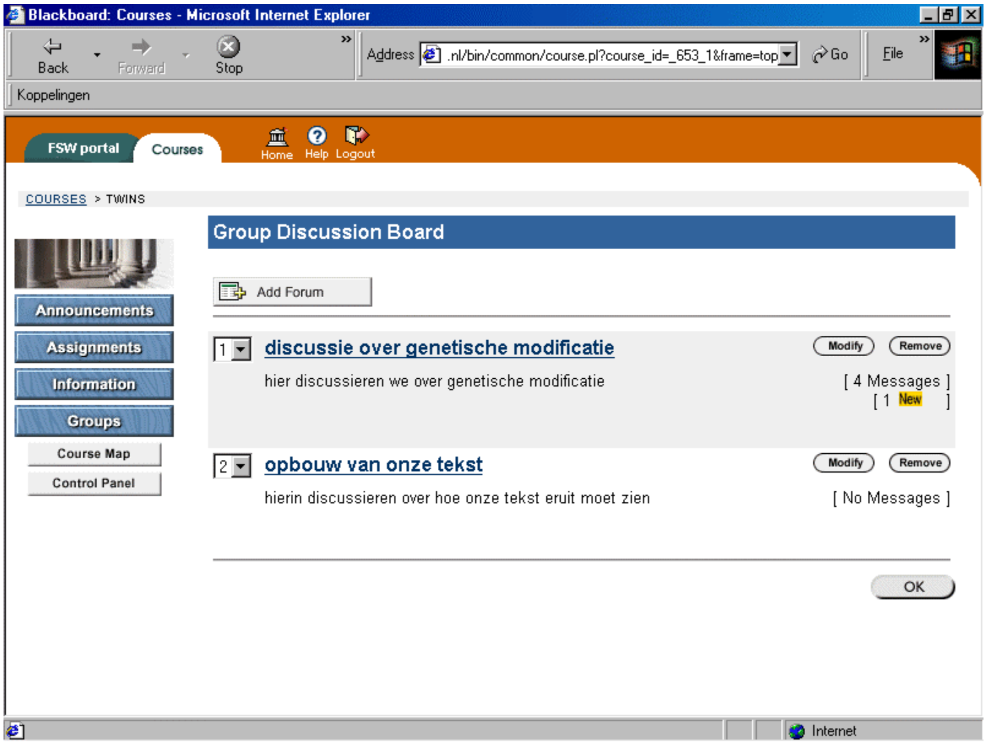

Figure 2. Screenshot of Blackboard®.

Measures

Data collection

The data consisted of all utterances in chat and discussion board. In principle, the unit of analysis in chat consisted of every separate utterance, marked by pushing 'enter' or by turn-taking. When an utterance required more than one code, the utterance was split. If students pushed 'enter' before ending their message, then the two chat utterances were subsequently merged for analysis. The messages in the discussion board were split in units of meaning. The coding of utterances and actions in the protocols was carried out with the computer program *MEPA* (Multiple Episode Protocol Analysis; Erkens, 2002).

Task acts

A first analysis was carried out in which all utterances were coded on the task-function which consisted of six main categories of task acts: outside activity, social relation, interaction management, task management, argumentative activities, and conceptual activities. Outside activity consisted of utterances not constitutive of the interactive space imposed by the researchers. Social relation consisted of utterances about interpersonal relations related to the task. Interaction management contained utterances about managing the interaction such as checking presence and turn-taking. Task management was talk about managing the task at hand. Argumentative activities were utterances containing argumentative moves. Conceptual activities contained utterances about concepts that could not be defined as argumentation. Inter-rater agreement on 10 protocols was .80 (Cohen's Kappa).

Argumentative Interactions

Argumentative activities were coded with a separate coding system based on Kuhn (1991) in the categories shown in Figure 3. The place of one argumentative interaction within a sequence of argumentative interactions defines whether it is an opinion, a supportive theory, an alternative theory, a piece of evidence, a counterargument, or a rebuttal. All codes are accompanied by the label 'asking' or 'giving'; whether an opinion or argument is asked for or given by a student. This makes clear how often students question each other, a feature of constructive dialogue. Inter-rater agreement on ten protocols was .82 (Cohen's Kappa). The coding systems of task acts and of argumentative activity formed the basis for a more extended analysis of the breadth and depth of interactive argumentation. The breadth of the space of debate was defined as the number of argumentative sequences counted, including all single utterances not followed by argumentative elaboration. To define the depth of an elaboration, the number of arguments in a sequence of related argumentative activities was calculated. For example, when students gave a claim, a supportive theory, and evidence for this supportive theory, the sequence was Claim–Supportive–Evidence and the depth score of three. In this way, all sequences of argument elaboration are tallied for their depth.

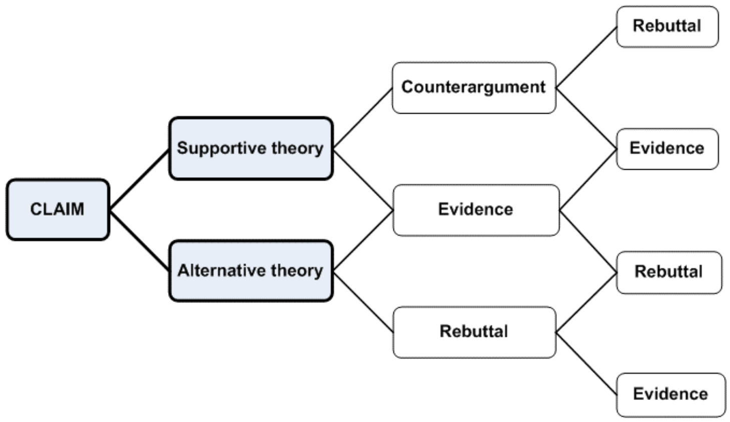

Figure 3. Argumentative Activities.

Argumentative text quality

The quality of argumentation in the argumentative texts written by the dyads was examined in order to determine whether different modes of communication during the discussion phase resulted in different quality of argumentation in the text. For this purpose, an instrument was developed which assessed the *quality of grounds* used in the text and the *conceptual quality of arguments* used in the text. The instrument was based on the work of Clark and Sampson (2005) and Schwarz, Neuman, Gil, and Ilya (2003). The quality of grounds refers to the way students used evidence for forming their opinions. It is comparable to what Schwarz et al. calls the acceptability of an argument. The conceptual quality of arguments refers to the conceptual adequacy of the arguments and counterarguments in the context of GMOs. A driving question in this respect was: Do students include correct concepts and information in their argumentation?

The quality of grounds was measured on a 4-point scale, with 0 indicating no grounds for the argument used, 1 indicating using a short explanation as a ground, 2 indicating that an elaborated explanation or example was used as a ground, and 3 indicating explicit reference to empirical data or everyday experiences as a ground. The conceptual quality of the arguments was also measured on a 4-point scale, with 0 indicating that the argument only contains conceptually incorrect components and 4 indicating that the argument contained several conceptually correct components.

Results

Task Acts in Discussion

Figure 4 shows the proportions of the different Task Acts. Because the dependent variables of the Task Acts were correlated and showed many outliers, Mann-Whitney U-tests were performed. A Mann-Whitney U-test is the nonparametric counterpart of the independent samples *t*-test which is robust for outliers and for violation of the assumption of normality. Mann-Whitney U-tests showed significant differences ($\alpha = .01$; Bonferroni correction) between the chat-condition and the discussion board condition for the variables outside activity ($U = 80$, $p = .00$), social relation ($U = 44$, $p = .00$), task management ($U = 93$, $p = .01$), and argumentative activity ($U = 24$, $p = .00$). Students using chat talked more about things not related to the task ($M = 0.06$, $SD = 0.08$) and social relations ($M = 0.09$, $SD = 0.09$) during collaboration than students using the discussion board ($M = 0.01$, $SD = 0.02$, and $M = 0.02$, $SD = 0.02$, respectively). Along with this, students in the chat condition made more utterances about the way they had to accomplish the task ($M = 0.51$, $SD = 0.13$) than students using the discussion board ($M = 0.34$, *SD* = 0.20). For argumentative activity it was the other way around, with students using the discussion board acting more on the argumentative level (*M* = 0.44, *SD* = 0.22) than students using chat (*M* = 0.14, *SD* = 0.11).

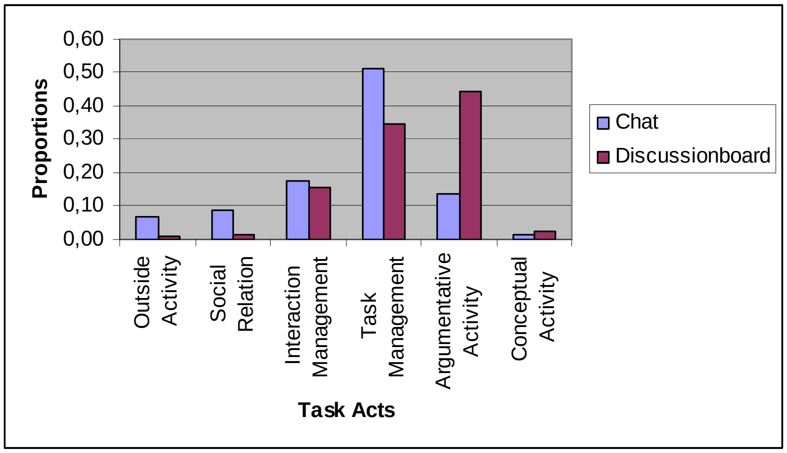

Figure 4. Task acts in proportions for both chat and discussion board condition.

Argumentative Activity in Discussion

The next step was analysis of the task-act category argumentative activity. Exploration of the different argumentative acts showed that almost all acts are non-normally distributed with many outliers. Transforming variables did not lead to normality, so Mann-Whitney U-tests were also carried out on these data. The Bonferroni correction set the alpha value again on .01. Table 1 summarizes the results of these tests. The Mann-Whitney U-tests showed that students who communicated asynchronously using the discussion board produce significantly more evidence and alternatives and that there is a trend towards using more rebuttals and verification questions.

Table 1: Results of Mann Whitney U tests between dyads communicating through chat en dyads communicating through discussion board.

	Chat condition (*N* = 20)		Discussion board condition (*N* =19)		Mann Whitney U		
	M	*SD*	*M*	*SD*	*U*	*z*	*P*[1]
claims	0.13	0.07	0.11	0.10	141.0	-1.377	.09
supports	0.19	0.09	0.14	0.10	139.0	-1.434	.08
alternatives	0.09	0.07	0.16	0.11	110.5	-2.235	.01
counterarguments	0.04	0.04	0.03	0.04	166.5	-0.695	.26
rebuttals	0.10	0.11	0.15	0.10	129.0	-1.729	.05
evidence	0.14	0.09	0.22	0.10	108.5	-2.291	.01
verifying	0.11	0.10	0.06	0.06	121.5	-1.933	.03
agreeing	0.14	0.08	0.12	0.13	145.5	-1.252	.11

[1]*One tailed significance*

Breadth and Depth of Discussion

Figure 5 shows the breadth and depth of the collaborative and individual argumentative sequences. Exploration of the frequency of argumentative sequences (i.e., breadth) and the mean length of argumentative sequences (i.e., depth) showed non-normally distributed variables with many outliers. Mann Whitney U tests showed that there was no difference in the total number of argumentative sequences (i.e., argument breadth) between chat and discussion board, *U* = 149.5, *p* = .13, while the total amount of collaboratively constructed argumentative sequences was higher for chat (*M* = 4.63, *SD* = 3.27) than for discussion board (*M* = 2.40, *SD* = 3.97), *U* = 86.5, *p* = .00. The mean length of the argumentative sequences (i.e., argumentative depth) in the chat condition was significantly longer (*M* = 2.52, *SD* = 0.84) than in the discussion board condition (*M* = 2.52, *SD* = 0.84), *U* = 98,

$p = .01$. This difference was mainly due to the significant difference between chat ($M = 3.44$, $SD = 1.57$) and discussion board ($M = 1.74$, $SD = 1.86$) in the length of the collaborative sequences, $U = 102.0$, $p = .01$.

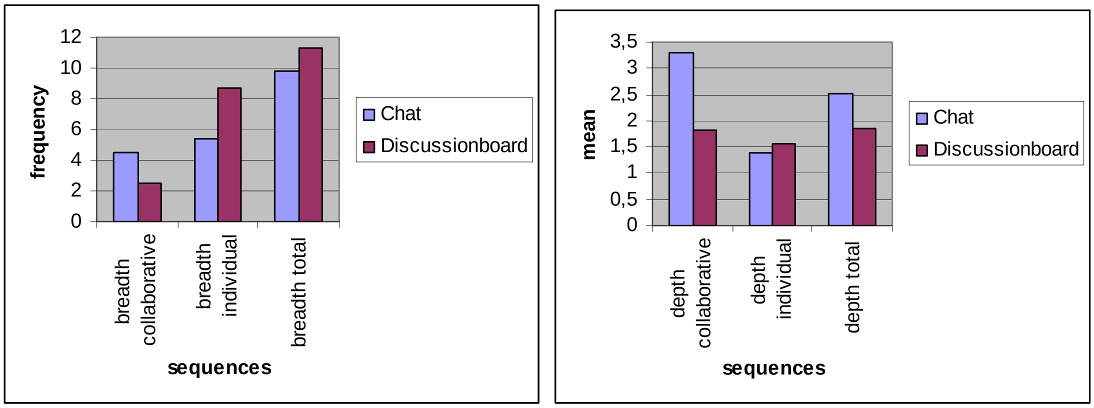

Figure 5. Frequency of argumentative sequences (breadth) and mean length of argumentative sequences (depth) in discussion phase

Quality of Grounds and Concepts in the Argumentative Texts

To detect the differences on the quality of grounds and concepts of the texts a MANOVA was performed on the two conditions and on the variables quality of grounds and quality of concepts. This analysis revealed an overall significant difference, $F(2, 38) = 2.50$, $p = .05$, $\eta^2 = 0.12$ which was due to a univariate effect on the quality of concepts ($F(1, 39) = 5.13$, $p = .05$, $\eta^2 = 0.12$). Students in the discussion board condition wrote conceptually better texts ($M = 1.56$, $SD = 0.42$) than students in the chat condition ($M = 1.31$, $SD = 0.30$). Another MANOVA on the quality of concepts in the different argumentative acts, supportives, alternatives, counters, and rebuttals revealed an overall significant difference, $F(4, 36) = 2.10$, $p = .05$, $\eta^2 = 0.19$ and univariate statistics showed significant differences on the variables supportives ($F(1, 39) = 3.23$, $p = .04$, $\eta^2 = 0.08$) and rebuttals ($F(1,39) = 3.78$, $p = .03$, $\eta^2 = 0.09$). Students using a discussion board used more correct concepts in their supportives ($M = 7.62$, $SD = 3.07$) and rebuttals ($M = 5.33$, $SD = 3.02$) than students using chat ($M = 6.55$, $SD = 4.00$; $M = 4.95$, $SD = 5.22$).

Conclusion and Discussion

Synchronous and asynchronous CMC was compared with respect to their influence on the way students argue in dyads. It was hypothesized that synchronous communication supports students in convergence processes or, in other words, on supporting the processes of collaboratively deepening a subtopic in the space of debate. An asynchronous mode of communication was thought to support conveyance processes, which is seen as broadening the space of debate, searching for different points of view. The results confirmed the first hypothesis. Despite more argumentative activity and the occurrence of more alternative theories and use of evidence in the discussion board condition, the analyses of depth of discussion showed that students in the chat condition have longer argumentative sequences, thus that they elaborated more on the same supportive or alternative theory. The second hypothesis was not confirmed by the results; the students using a discussion board did not talk about more topics and perspectives than the students using chat. On the contrary, the results showed an opposite effect with students using chat being broader in their discussions than students using the discussion board. The third research question on whether there is a difference between students in the synchronous and the asynchronous CMC conditions on the quality of a subsequently written argumentative text. The hypothesis was that students who discuss more deeply will write texts with a higher quality of evidence and will more accurately use concepts. The results showed the opposite for the quality of concepts in the argumentative texts. Students who discussed the subject of GMOs using a discussion board used more correct concepts in their arguments than students who discussed the subject using a chat box.

In contrast to earlier findings that synchronous CMC is not conducive to deep learning and is not really beneficial for carrying out complex communication tasks, these results show that synchronous CMC does have the ability to stimulate both a broader and deeper discussion when compared to asynchronous CMC. It appears that the affordance of immediate feedback - the possibility of reacting directly to what another student is saying - stimulates students to negotiate and argue with each other. Nevertheless, despite a broader and deeper conversation between synchronously communicating students this did not lead to more accurate concepts in the argumentative text. It appears that students communicating via a discussion board have a better and more accurate understanding of the different concepts relating to the topic of GMOs, indicating that they have achieved a better understanding of the meaning of the different pieces of information. However, it is possible that it is not the discussion between the students that is responsible for this more accurate understanding of the concepts, but rather the fact that students using the discussion board had more time to process information and verbalize it in their individual messages.

Some possible limitations of this study should be considered. First, the results raise some interesting issues concerning how students use different media. It is possible that students use media in such a way that they do not make optimal use of CMC's affordances. Van der Pol (2002), for example, shows that it is difficult for students to react in a specific and relevant way to messages of other students in a discussion board, despite the time available for reflection due to the asynchronicity of this type of communication. There is little research relating to how students rehearse and reprocess in asynchronous CMC environments. It appears that rehearsability helps students to process information in a message, but questions remain as to whether they take the time available to reflect on the messages of others and on what kind of thinking processes take place during such reflection. A second limitation involves whether comparing synchronous and asynchronous CMC is an adequate and valuable approach. Johnson (2006) concludes in her review of recent research on synchronous and asynchronous text-based CMC that both forms of online discussion have advantages and that there is evidence that both forms contribute to student learning outcomes. She argues that systematic and objective research on how synchronous and asynchronous online discussion can be combined is needed. It is possible that the effectiveness of different media is mediated by individual difference variables, such as the student's experience with synchronous and asynchronous CMC. The fact that students in our study argue both broadly and deeply in synchronous CMC could be due to the experiences that they have had with chatting in general. Finally there are some methodological issues that need to be mentioned. In this study, the quality of argumentation during discussion is measured by the breadth and depth of the argumentative sequences. However no correlations were found between the breadth and depth of the sequences during discussion and the argumentative quality of the final product. This raises the question as to whether breadth and depth are sensitive to differences in the *quality* of argumentation or are they just measuring frequency differences in the argumentative sequences. Future research should, thus, also to look at the quality of the grounds and concepts in the argumentative sequences and try to determine whether students construct specific sequences in different forms of CMC.

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Toward collaborative technologies supporting cognitive skills for mutual regard

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Abstract: In this paper I elaborate on a promising link between ethics, thinking skills, and online collaborative tools. Cognitive tools used for communication and collaboration can be designed to support and scaffold ethically-relevant skills such as: cognitive empathy, the ability to take multiple perspectives, the ability to reflect on one's biases and emotional state, a tolerance for uncertainty, ambiguity, and change, and the ability to reflect upon the quality of a communication that one is involved in. These thinking skills contribute to the quality of knowledge building and decision making. I argue that an opportunity now exists to source this large body of related work to create a coherent R&D focus.

Introduction

Can technology help people develop ethical and moral skills and sensibilities? The question itself may seem alien or meaningless—technological innovations are usually assumed to be value neutral. Though it is true that a technology can be *used* to support any set of values, including both ethical and non-ethical means to an end, almost universally technology is *designed* to support values such as productivity, efficiency, accessibility, and connectivity. Can technology be not only be used to support ethical ends but be explicitly *designed* to support values such as mutual regard and self-awareness and enhance ethical ways of being?

In this paper I will elaborate on a promising link between *ethics, thinking skills,* and *online collaborative tools*. My treatment of "learning environments" will be geared to life-long learning contexts and communities of practice engaged in knowledge building and decision making (however, the principles are easily applied to student learning communities). By *ethics* I mean the simple moral concept of individuals or groups treating each other with mutual recognition and regard. My argument can be summarized as follows: (1) in the modern (or post-modern) world, being *ethical/moral* involves (not exclusively but importantly) a set of *cognitive skills*, including: the ability to put oneself in another's shoes (cognitive empathy), the ability to take multiple perspectives, the ability to reflect on one's biases and emotional state (a type of metacognition), a tolerance for uncertainty, ambiguity, and change (a type of epistemological understanding), and the ability to reflect upon the quality of a communication that one is involved in (meta-dialog). (2) Online *collaborative software* (or "cognitive tools") can be designed to support these skill sets by embedding certain protocols, structures, prompts, and other scaffolding devices into existing communication media. (3) More strongly ethical modes of collaboration improve the quality of *knowledge building and decision making*.

A broad interdisciplinary set of research projects and results can be seen as relevant to this thesis, but very few describe what they are doing in terms of this ethics/thinking-skills/collaborative-tools relationship. My purpose for writing this paper is to suggest that more can be done to bring these threads (ethics/thinking skills/cognitive tools) together and spark new R&D that could lead to technologies that demonstrably support mutual regard at both small (among individuals) and large (inter-group) scales. (Note: an extended version of this brief paper is available at [Murray 2007]; and also see the related Workshop description for "Technology Supporting Cognitive Skills for Ethics in Collaboration and Communication" in these proceedings.)

Ethics, knowledge building, cognitive skills, and online tools

Ethics and knowledge building. There are important links between ethical ways of being and knowledge building. As more and more of society's work (and individual's play) revolves around information, knowledge, and learning, the quality of knowledge building and organizational learning becomes more critical. In his work on communicative action and "discourse ethics" philosopher Jürgen Habermas claims that for collaboration to move us in the direction of more adequate (if still tentative) truths it must have certain properties that are fundamentally ethical/moral (Habermas 1993, 1999). These properties include: that sufficient mutual understanding regarding key concepts and assumptions is established; that all important or relevant points are heard; that dissenting opinions are sincerely considered; that speech is honest and without hidden agenda; that the power dynamics of the situation are reflected upon; and that participants actively engage in opening up to the sometimes unsettling world views of others. Problems in any of these areas can result in systematic bias or distortion in the outcomes of knowledge-building. Thus, moral constructs such as freedom, equality, empathy, sincerity, inclusivity, reciprocity, integrity and mutual regard are deeply entangled with the knowledge building processes of discovering ever more adequate truths.

If we move beyond the scope of human endeavors implied in "knowledge building," we can find scholars studying an array of interdisciplinary concerns including business success, civic vitality, and psychological health, who make links to ethics-related constructs and the skills of care-full communication and collaboration. We will not go into these works further in this short paper, but simply summarize by stating the assumption that skills, habits, and attitudes related to basic ethical orientations are fundamental to individual and social success in numerous areas.

Ethics and cognitive skills. Exercising ethical capacities such as mutual regard involves a combination of intellectual, perceptual, emotion, motivational, and attitudinal elements. We use the broad sense of "cognitive" to cover all of these areas (as opposed to the narrow sense of "cognitive vs. affective"). The full spectrum of ethical considerations includes an ability to perceive the ethically relevant aspects of a situation (Vetlesen 1994); empathic capacities (Goleman 1995); and the desire, commitment, and will to act on ethical values (Taylor 1991). Thus, it is impractical if not impossible to try to operationally separate rational skills from emotional/social skills in this area, as both are so interdependent. The thinking and communicating skills/habits we are interested in include capacities to: 1) consider or try on the perspectives of others ("cognitive empathy"); 2) engage in productive dialogs of inquiry to build mutual understanding; 3) reflect on one's thoughts, values, biases and emotional states; 4) tolerate uncertainty, ambiguity, paradox, and change in knowledge and circumstances; 5) reflect upon the quality of a communication that one is involved in.

Elsewhere (Murray 2003) I have described ethical modes of interaction in terms of two general categories of skills/habits: perspective and integrity. The list of skills above are perspective taking skills. *Perspective* taking includes the abilities to "step out" to reflect on one's own thoughts or ideas, "step in" to (try to) see the world through another's eyes, and "step back" to take a systemic perspective on an entire situation. *Integrity* involves such things as transparency, responsibility, and accountability, which are essential to have a full account of being ethical. Integrity can be defined as follows in terms of maintaining *congruence* between: one's words and actions (doing what one says they will do); one's words from one situation to another (not saying contradictory things in different contexts); and one's inner beliefs/intentions and ones words (being honest and authentic).

This description of ethical modes of interaction is not meant to be exhaustive. It is given to sketch out the scope of the skills/habits I refer to as important to ethical ways of being. In this paper I will not define these skills precisely in an operationalized and measurable way, though such precision would be a prerequisite to empirical research and theory building. Metacognitive and epistemological sophistication are clearly woven into the skill sets mentioned above (and see [Basseches 2005] on dialectical thinking, [Kegan 1994] on subject-object theory, King and Kitchener [1994] on reflective judgment).

Technologies and contexts supporting ethics-relevant skills. The working hypothesis of this paper is that features can be added to existing forms of online tools (discussion forums, web sites, decision support tools, etc.) that will *scaffold and prompt* for the use of ethical skills/habits, and will thus support the *learning and adoption* of those skills/habits. Software can enforce or promote behavioral protocols and can reify (make explicit) social values and conceptual frameworks related to ethics. There are two complimentary types of outcomes. First, technology can enforce or structure *interactions* and communications so that users follow some protocol (but do not necessarily learn anything in the process). Second, technology can also support an *internalization* of skills and values, thus scaffolding learning as well as behavior.

Socially conveyed and intentional forms of learning are mediated through designed artifacts (Jonassen & Rohrr-Murphy 1999, Vygotsky 1978). Digital technologies afford unique opportunities to consciously tailor the medium/environment of communication to support certain values and habits in collaborative work (Winograd & Flores 1986). The ethics-supporting software features alluded to here are seen as most applicable to *well-defined groups with sufficient shared goals or values.* Such groups might include: employees of a company that orients strongly around ethical values; a community of scholars furthering some field of knowledge; participants in an international diplomatic deliberation; civic deliberation or conflict resolution forums; and fact-gathering volunteers in an NGO. If those in a group's leadership role want to encourage certain values in the group, *and* there is sufficient buy-in from group members to engage in the learning curve of trying something new, then these collaborative technologies can play a pivotal role in transforming or sustaining ethically-sound thinking/practices in a group.

People do not always live up to their own expectations, standards, or competence levels in terms of ethical behavior. Depending on the context, the dynamics of group behavior can create least-common denominator results (such as crowd mentality) where group interactions lead individuals to act in cognitively and/or ethically degraded ways, or, alternatively, can lead to positive synergetic effects in which group interactions lead individuals to act with higher overall cognitive and/or ethical capacities (Surowiecki 2004). Key ingredients to creating "collective intelligence" as opposed to collective inanity are shared intention and a supportive environment or culture, which includes a group's communication artifacts and procedures.

Related Research and Projects. Research related to our concerns falls into several categories, such as: 1) *Research in cognition and epistemology*, including the unavoidable indeterminacies in concepts and models; research into so-called "bounded rationality;" and developmental studies of epistemic sophistication and its relationship to ethical reasoning. 2) *Research in communication theory and social linguistics* related to mutual understanding, mutual agreement, and mutual regard. Including research in applied hermeneutics, meme evolution, and argumentation integrity and fairness. 3) *Research on human emotional and social capacities*, both from brain science and from psychology. This research is important because of the strong emotional factors in developing relationships of high trust (with its concomitant vulnerabilities), attachment to tightly held beliefs, and tolerance and resilience to cognitive dissonance. 4) *Research in cognitive tools supporting dialog, knowledge building, and epistemic sophistication*, including research on fostering metacognition, self-regulated learning skills, reflective reasoning skills, "cognitive flexibility," and multiple perspective-taking. Online tools for democratic debate and public deliberation (so-called cyber-democracy and e-deliberation) are also being tested, and other projects study how trust, reputation, and credibility are built and measured in online environments. Finally, immersive virtual reality and role playing games are being developed on ethics-related themes.

Further reading and next steps. In [Murray 2007] I describe more specifically some of the software features alluded to here, give numerous references to related research, and describe orienting directions for the emerging field of technology for ethics-related thinking skills.

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Process- and context-sensitive research on academic knowledge practices: Developing CASS-tools and methods

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Abstract: The Contextual Activity Sampling System (CASS) methodology and CASS-Query tools have been developed for the investigation of learning and working practices. The CASS-methods and tools provide contextualized data that allow the analyzing and modeling of within-person changes across time. This paper describes a pilot study with 3G mobiles used by eight engineering students. Students answered questionnaires concerning their ongoing study projects, academic emotions, and collaboration, with a mobile phone five times a day for a period of two weeks (70 queries per person). Variation in their emotions were examined by time-series analysis. Students were also interviewed before and after the CASS-query period. Interview and query data were used to form a picture of the variation of daily routines, challenges, and reflections of one's own activities related to engagement in academic tasks or leisure. The study reports results regarding students' experiences of the CASS-methodology, emotional experiences during the two-week follow-up, their objects and activities related to personal study projects they undertook during this period.

Aims

Traditional methods of learning research are usually individually oriented, focus on the participants' beliefs and other discursive entities rather than their practices as they occur. Therefore such methods provide a frozen picture of students' behavior rather than address sustained processes of individual and social transformation. The participants are often asked to provide retrospective global assessments (Reis & Gable, 2000) of their beliefs and conceptions of learning that are assumed to determine the nature of their concrete approaches to learning. There are few empirical studies linking students' predispositions to actual practices, other than studies where students have been asked to report how strongly they prefer various study strategies. Several learning researchers (e.g., Engeström, 1987; Marton and Trigwell, 2000; Säljö, 1997; Wegner, 1998), argue, by contrast, that social practices play a central role in learning and instruction. Further, Gale (2002) and Quinn (2004) point to the sociocultural explanations of students' difficulties in higher education. Overall, everyday institutional practices of working with knowledge-- taking courses, reading, writing, presenting, interacting with other students, as well as the structuring of activity in space and time, by the curriculum -- appear to be in a central position in determining also individual practices of learning. Evidently, these variables are interacting with students' personal dispositions. However, understanding of the contextualized factors of learning, which are cross-time, cross-situational, and multilayered, is currently rather primitive (Alexander, 2002). In short, research on sociocultural dynamics of learning and instruction appears to require transformation of available research tools.

One of the central aims of the present investigation is to develop and validate contextual tools for longitudinally analyzing transformation of university students' knowledge practices, i.e., processes, routines, or procedures of working with knowledge. Knowledge practices represent socially constituted, rather than merely individual activities (Hakkarainen et al, 2006). Background for methodological development is provided by the Ecological Momentary Assessment (EMA) (Bolger, Davis, & Rafaeli, 2003; Reis & Gable, 2000; Stone & Shiffman, 2002) and Experience Sampling Method (ESM) (Csikszentmihalyi & Larson, 1987) which provide methods of assessing participants' contextual activities, events, and personal experiences. Whereas ESM focused originally on capturing elusive flow experiences, EMA is more broadly oriented toward recording mundane and routine everyday activities that constitute social practices. The participant is asked to assess only one situation in time and generalizations are made by researchers by aggregating observations or modelling changes across time.

Developing and validating The Contextual Activity Sampling System (CASS)

The CASS-query tool is a Java-application for collecting process- and context-sensitive data. The system is implemented on 3G mobile devices (e.g., Nokia N93) with Symbian operating system, MP3, video, GPS, wlan. The CASS system provides generalizable tools in open-source terms (i.e., adaptable and free of charge) that can, in a flexible way, be tailored and elaborated for particular needs and requirements of researchers and users.

Basic functionalities of the CASS-Query tool include:

- Administrator tool (XML-editor) enables the construction of queries, defining questions and types of responses (open text, Likert-scale, audio- or videorecording, picture) (figure 1).
- Queries are customizable to each user.
- The application connects to the Internet and downloads the intended query from the server.
- Responses are returned to server database.
- Data are transferrable to statistics software SPSS.

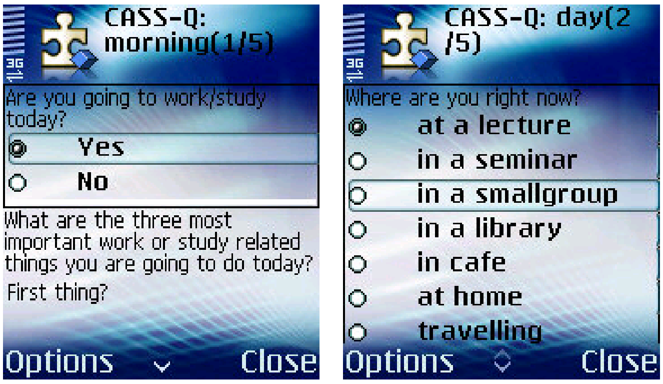

Figure 1. Screenshots from the CASS-query tool.

A *pilot study* was carried out with eight third-year students at EVTEK in November 2006. The students were interviewed individually after and before the pilot. They were introduced to the CASS data-collection procedure, queries, and mobile phone in an introductory session; a feedback session was held after the pilot. The actual pilot consisted of 14 days, during which the students were asked to answer to five queries each day. A daily set of questionnaires included morning query, three identical day queries and an evening query. The time spent in the morning and evening was approx. 5-7 minutes per query and for the day 2-3 minutes per query.

Examples of issues addressed were the objects (What are the personal projects defined as papers, exams, work, hobbies), self-efficacy and flow (How absorbed are you in what you do?, How competent do you feel?), stress (see Elo et al., 2003) (Do you feel stress?), affects (e.g., enthusiastic, nervous), social context (where, with whom), social sharing (Are you interacting with someone else?), obstacles and constraits (what hampers or restrains your activities). In analyzing the data, we will apply multi-level models, such as the time-series models adapted to repeated measures data.

Findings

The students in the pilot study considered the tool very easy to use, they became accustomed after two or three queries. The pilot study provided evidence that the sampling was able to show both within-person and between-person variation in the affect and motivation questions. We discovered, e.g, very different rhythms (some study from 8-4, while others start in the afternoon and continue late into the night), range in the number and type of personal study projects, type of constraits they experiences, and types of networks students were active in.

Theoretical and educational significance

It appears that the contextualized CASS-sampling provides investigators a novel type of information on learning and working practices. In future, a combined use of both within person (time-series) and cross-sectional (between groups) analyses appears feasible to extend understanding of knowledge practices beyond single individuals (Schmitz, 1990).

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Exploring Embedded Guidance and Self-efficacy in Educational Multi-user Virtual Environments

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Abstract: In this paper, we present the results of an exploratory study into the relationship between student self-efficacy and guidance use in a Multi-User Virtual Environment (MUVE) science curriculum project. We examine findings from a group of middle school science students on the combined effects on learning of student self-efficacy in science and use of individualized guidance messages. In addition, we report on findings that demonstrate the interplay between levels of self efficacy in science and use of an embedded guidance system in an educational MUVE.

Problem

In this paper, we describe a study probing the possible relationship between students' guidance use in an educational multi-user virtual environment (MUVE) and their self-efficacy in science, as well as the combined impact on learning of guidance use and self-efficacy level in an educational MUVE designed to teach scientific inquiry skills and experimental design to middle school students.

Our study centers on the River City graphical MUVE. In River City, small teams of students develop and test hypotheses about why residents of the town are ill. During a 12 session curriculum, students experience a year of virtual time in River City. Students first gather information over the course of four seasons in River City. This is followed by classroom-based experimental design group work. Students then re-enter River City to test their hypothesis in "control" and "experimental" worlds, which differ by one factor chosen by each team based on its experimental design. Students then write to the town mayor describing their hypothesis, experimental design, and results (Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005).

Self-efficacy in scientific inquiry refers to a student's belief that they can conduct scientific inquiry; it is a measure of their confidence in conducting inquiry activities. Researchers have investigated both the origin of a person's self-efficacy and its effect on behavior. Of particular interest to this study is whether there is a relationship between self-efficacy and accessing guidance. Evidence for this relationship is equivocal with studies showing widely divergent results regarding whether high or low self-efficacy students are more likely to show help-seeking behaviors and whether this behavior is beneficial for learning or not (Pajares, 2004).

To explore the relationship between science self-efficacy and guidance use in River City, an embedded guidance system was added to the MUVE. The system monitors student activities to display text-based hints designed to assist them in understanding data found in the MUVE.

Use of the guidance system in River City relies on students' willingness to make use of it. Consequently, it is likely that use of the embedded guidance reflects the research on self-regulated learning and thus indicates that students with high self-efficacy would be more likely to access the guidance messages than students with low self-efficacy in science.

Research Questions

The research questions in this study are:

1. *Do students with low self-efficacy in science view fewer guidance messages within a MUVE-based science curriculum than students with high self-efficacy in science?*
2. *Do students with low self-efficacy in science who view guidance messages within a MUVE-based science curriculum perform as well on content tests as students who report high self-efficacy in science?*

Population

This study presents results of a 2004 implementation with 102 seventh-grade students who were provided access to embedded guidance in the River City MUVE.

Procedures

Students had access to a guidance system featuring continuously updated links to hints. Students could view three hints per pre-defined information object in River City. Whenever students clicked on a specially tagged object inside the MUVE, the guidance system flashed alternating colors to signal that new hints were available. To view messages, students clicked on the hint buttons, allowing us to track when students viewed guidance messages and which messages they saw.

Measures

Qualitative and quantitative data were collected. Pre- and post-intervention, students completed an affective measure adapted from three surveys; Self-Efficacy in Technology and Science (Ketelhut, 2005), Patterns for Adaptive Learning Survey (Midgley, 2000), and the Test of Science Related Attitudes (Fraser, 1981). To assess science inquiry skills and biology knowledge, we administered a 30 question content test, pre- and post-intervention with an internal consistency reliability of .80 in a middle school population.

Students' self-efficacy in scientific inquiry was measured using a subscale in the affective measure containing 12 items, each rated on a scale from 1 (low) to 5 (high) (Ketelhut, 2005). Overall scores are computed by averaging the student's responses across the twelve subscale items, with high scores representing high self-efficacy. The measure has an estimated internal consistency reliability of .86.

Findings

In answer to our first research question, we found that students with low initial self-efficacy in scientific inquiry viewed significantly fewer guidance messages ($p<.05$) than their higher self-efficacy peers. For example, a student with an initial self-efficacy score of 1 would view approximately 14 fewer messages on average than a student with a self-efficacy score of 3. In addition, it was found that boys viewed significantly fewer messages than girls ($p<.05$) overall, and across a range of initial science self efficacy scores ($p<.05$).

To assess the second research question, we first regressed student post-test scores on levels of guidance system use and pre-test scores. In this analysis, we found that viewing guidance had a significant positive impact on post-test scores ($p<.01$). In other words, holding pre-test scores constant, students who viewed more guidance messages out-performed students who viewed less. To investigate whether low self-efficacy students who viewed guidance performed as well as students with higher self-efficacy, we added initial level of self-efficacy in science to our model. We discovered that self-efficacy also predicted for post-test content scores in a model with guidance views ($p<.05$).

Conclusion

This exploratory study indicated that (a) students with low self-efficacy in science view fewer guidance messages embedded in an educational MUVE than students with higher self-efficacy, and (b) students who view more guidance messages outperform those who view fewer, with high self-efficacy students outperforming lower self-efficacy students across a spectrum of guidance use. With well-designed educational MUVE-based curricula incorporating embedded guidance and engaging inquiry, we hope that all learners can better understand and apply principles of real-world science inquiry.

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The Fourth Man – Supporting Self-Organizing Group Formation in Learning Communities

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Abstract: In this paper we propose an approach based on social network analysis facilitated by ontologies for the support of learning group formation in computer supported collaborative and blended learning scenarios. This approach allows us to generate new ties between learners who are interested in similar topics. The identification of similar topics is elaborated dynamically by using a shared workspace environment which supports visual editing and modeling of topic relationships.

Introduction

In recent years blended learning is getting more and more important in the day-by-day teaching and learning at Universities, in further education and even at schools. Course materials are available online as well as the exercises, and the students are expected to work on the particular topic in a self-responsible manner. Many learning scenarios and courses try to combine collaborative and blended learning (e.g. Harrer et al. 2005) – especially in the online phase of the blended learning setting. While even for strict presence learning scenarios the choice of the most adequate group formation mechanism to achieve the learning goal at hand may be a problem, although learners and teachers know each other, e.g. in classroom scenarios, the online phase often adds the problem of not being aware of each other. In a classroom it is obvious if a student has not found a group to work with, because he or she will not be sitting at a group desk. In an online scenario the natural overview on the group formation is reduced and at most visible to the teacher, since persons not assigned to a group should not be exposed to the whole learning community. Although the teacher may be able to intervene in such a group formation situation, we think it would be better to help the students themselves to solve the group formation problem since the self-organization of the students is often a sub goal of the collaborative task.

Systems that explicitly target group formation (Ikeda et al., 1997; Mühlenbrock, 2005) usually require information about user profiles. These are usually domain specific and not easily transferable. On the other hand software products or web-based education installations usually provide one or more communication channels enabling the students to discuss with each other. One of the analysis approaches for such communication is Social Network Analysis (SNA; Wasserman & Faust 1994). It has pointed out the impact of group structure for the learning processes and outcomes (Reffay & Chanier, 2003; Harrer et al. 2005; Martínez et al. 2006). This kind of awareness about group structure is the first step to recommendations addressing group formations. Currently known approaches usually do not support the explicit recommendation of learning partners while protecting the privacy of the students to avoid open social conflicts at the same time. In this paper we propose an approach (Malzahn et al., 2005) based on SNA and facilitated by ontologies (Gruber, 1992) for the support of learning group formation in computer supported collaborative (distance) learning scenarios. In the next sections we will sketch the approach and provide an example for the formation of such a group in a University course with more than 100 students which had to form groups for a software project. The paper closes with a conclusion based on the experiences made so far and the description of further scenarios.

The Approach

Web portals and discussion forums are currently a main source for communication and exchange of expertise both in academia and communities of practice. Popular forums like phpBB2 or FLE3 can be divided into categories to structure these threads. These categories are built of more or less broad topics. If the forum is large, i.e. concerning the amount of writers and categories, most persons know only a subgroup of persons directly involved in topics where they write themselves. Other persons might be interesting to get to know because they share similar interests or they are known as experts in other parts of the forum. In the case that a forum consists of subgroups which do not know or do not communicate with each other except through a small number of persons belonging to both groups, traditional social network analysis will fail to identify the important persons to get to know. Thus persons behind these cut points (Wasserman & Faust, 1994) will be invisible to the investigating person. This is even more emphasized when there are no boundary spanners, i.e. if the communities have no overlapping members. It is easily conceivable that persons who have similar interests participate in different parts of a large forum without having any direct or indirect connection in a communication-network. To be able to find a link between those persons an additional network-structure must be used. We propose that ontologies should be used to add missing links between persons who should be aware of each other. How this combination of a social network and an ontology is done can be found in Malzahn et al., 2005.

Example: Searching for „The Fourth Man“

Our approach was tested for validity in the context of a university course about „Software Engineering“ for undergraduate students of computer science. The course was organized as a blended learning scenario with presence lectures and exercises and extensive online materials manifested in a web portal with discussion forums, wiki etc. Carrying out a software project in groups of 3-5 students was required to pass the course (Harrer et al., 2005). The group formation was handed to the students themselves so that they had to self-organize the composition of the team. Some of the users used the discussion forum to find partners for completing their team. Interestingly this resulted in 3 fragmented threads (s. fig. 2 left) that were all about the search for „The Fourth Man“ of the team, but that were not connected with each other directly by joint discussants. They were not even organized in the same forum area. Our approach enables the user to connect the three threads related to students seeking project partners conceptually by creating an ontological relation. This can either be done by e.g. a teacher looking at the threads' topics or by an intelligent agent applying machine learning techniques such as text clustering. The algorithm combining the social network and the ontology produces a network where the students interested in the same topic are visible to each other across the thread's boundaries.

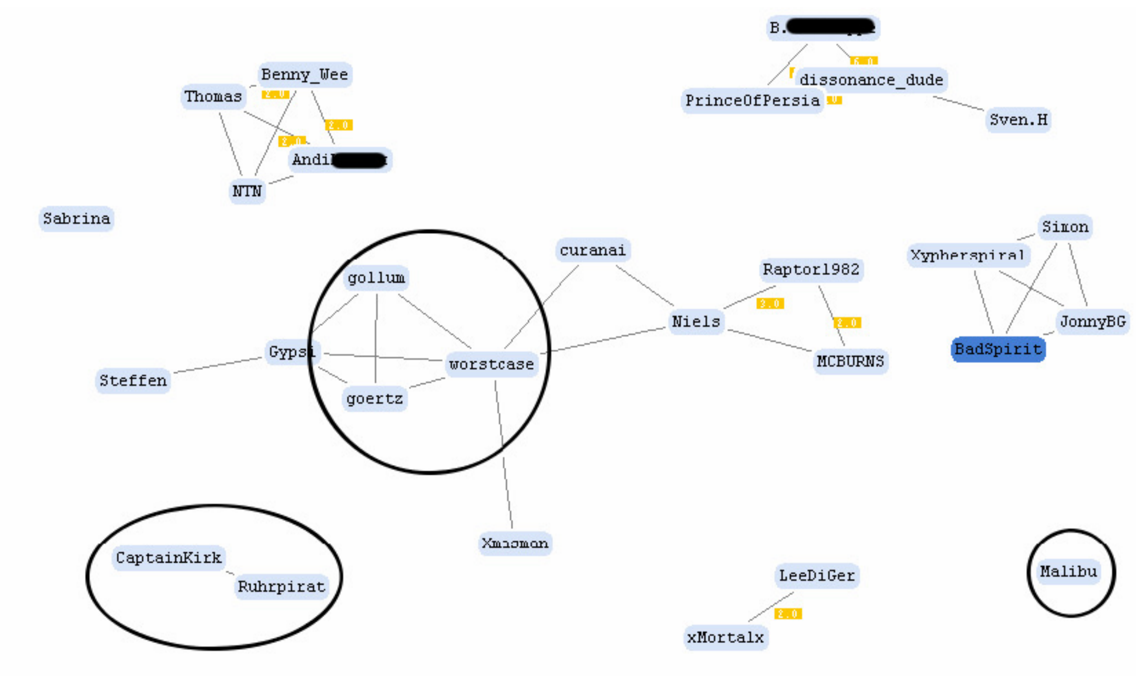

Figure 1. Original Network – Groups searching for the fourth man are highlighted

The original network (cf. fig. 1.) shows 3 groups, searching for additional members. For example the student using the nickname Malibu (fig. 1, lower right) posted once, asking for a fourth person to join his group but received no answer. So he was displayed as an isolated node in the original network. After linking the related topics he is now included in a bigger network. The network on the right of figure 2 shows only the differences between the original network and the resulting one focusing those students with a similar problem as Malibu. In previous courses we had to support this matchmaking manually, while the proposed mechanism makes it possible to support self-organization of the students and contribute to their own responsible acting. The smaller network on the left of figure 2 shows the "ontology" used to establish the relations between Malibu and the other students. The design of this network is an important step to the success of the proposed approach. As stated above the relations can be either set by a software agent relieving the teacher from this work especially in lectures with a high number of students or they can be facilitated by the teachers. This allows them to influence the group formation process as needed to reach the particular learning targets.

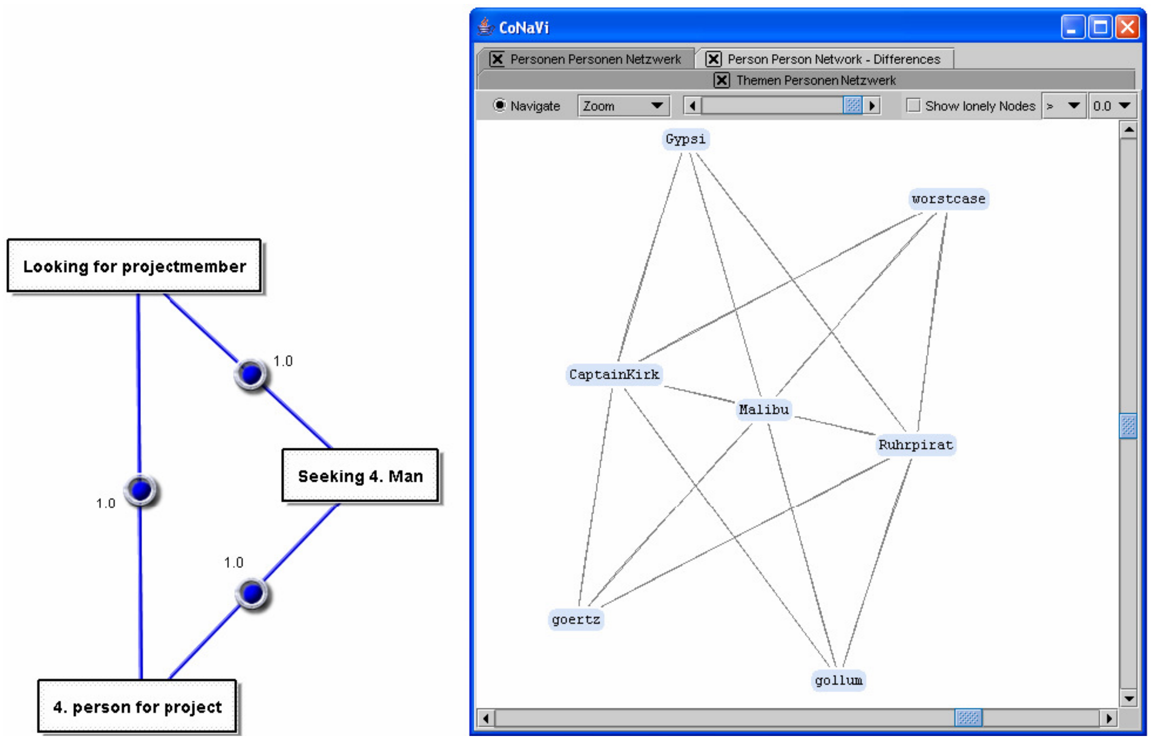

Figure 2. Emerging Relationships

Perspective and Conclusions

In this paper we showed how a collaborative blended learning scenario can be supported by the means of ontology facilitated social network analysis. We discussed how the teacher can create the relations between the forum topics to stimulate the group formation process. Another promising option might be to enable the students themselves in certain scenarios to relate the topics to each other to get a recommendation for partners in the collaborative scenario. This may have two effects: the students have to structure the domain of the task at hand, which might be a learning target in itself, and the students get a feedback of their own position in the group without touching the privacy of the others, because they will only get the information of their personal network. Looking onto the promising results with forums we expect that the concept of integration of ontologies into social networks can be extended to shared information spaces on a general level. This can be done by generalizing the concept of forum topics to learning process artifacts. Artifacts are used in different domains like learning environments (as Learning Object). Thus the same algorithm enables users of complex learning environments to reflect their position within the particular network.

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Argumentation Vee Diagrams (AVDs) Enrich Online Discussions

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Abstract: With online Argumentation Vee Diagrams (AVDs), students compose arguments on both sides of a controversial issue and then develop an integrated conclusion. In this study, students used AVDs prior to composing discussion notes, and—at the end of each discussion—jointly created a group AVD. AVDs significantly enhanced the number of arguments/counterarguments and compromises in students' discussion notes, and promoted opinion change. However, for AVDs to be effective, students also needed instruction on evaluating argument strength.

Introduction

A frequent problem with online discussions is that students often superficially agree with one another rather than exploring alternative views (Koschmann, 2003). Although interventions exist that promote disagreement (Baker, 2003), that is only half the problem. Students also need to critically evaluate both sides of controversial issue and to "put the pieces together" in formulating a final conclusion.

Nussbaum and Schraw (in press) termed this process *argument/counterargument integration*. Rooted in contemporary models of argument (Walton, 1996), integration can involve refuting arguments on one side ("refutation strategy"), finding a compromise/creative solution between two sides ("synthesis strategy"), or weighing advantages/disadvantages of the two sides ("weighing strategy"). Nussbaum (2006) found that students use weighing strategies the least because of the number of separate elements that must be coordinated in working memory. The most common strategy was *pseudo-integration,* where students simply picked an argument they "felt" was strongest but did not respond to counterarguments.

Nussbaum (2006) also assessed the effect of "Argumentation Vee Diagrams" (AVDs) on argument/counterargument integration, but in the context of writing opinion essays. The present study explores the effect of AVDs in online discussions. AVDs involve students listing arguments on both sides of an issue (specifically on different sides of a large "V"), but then, at the bottom of the figure, developing an integrated conclusion, which is subsequently used to compose a discussion note. Two questions were included at the base of the V to scaffold students' thinking: (a) "Which side is stronger, and why?" (weighing strategy) and (b) "Is there a compromise or creative solution?" (synthesis strategy).

AVDs were provided to student in two ways. First, students received blank AVDs (in WORD) and individually completed them before their discussions. (Schwarz & Glassner, 2003, found individual brainstorming before group discussion improved discussion quality by facilitating a greater variety of ideas.) After composing their initial notes, students were required to post additional notes indicating points of agreement and disagreement with others. Discussion groups contained three students each. Then, at the conclusion of their discussion, students used *Wiki*'s to compose a joint AVD and summary note. (*Wiki*'s are a Web-page that anyone in the group can edit.) Students learn more from discussions when they summarize the various points made (Schwarz & Glassner, 2003). In addition, because group roles can facilitate participation (Webb & Palincsar, 1996), we assigned three different roles: (a) Composer, who completed the initial group AVD, summarizing the discussion, (b) Elaborator, who added clarification, and (c) Integrator, who used the group AVD to compose a summary discussion note. This study investigated whether AVDs improved the quality of online discussions, as measured by numbers of arguments/counterargument, and extent of argument/counterargument integration.

Method

The study was a design experiment, which recognizes that complex interventions may need to be modified during implementation. To provide rigor, we also conducted the study as a quasi-experiment. The study used 87 participants enrolled in two sections of a distance course on educational assessment. Both sections were taught the same way and used identical materials. Students were required to post a minimum of two notes per discussion, and one student also had to write a note summarizing the discussion.

There were three discussions, each lasting one week. The discussion topics were: (a) Should students be graded on class participation, effort, and homework completion? (b) Should ability grouping be used to teach reading? and (c) Should states be required to have accountability systems for evaluating student performance? For the first discussion (experimental group), we developed several worked examples on how to complete the AVDs, presented to students using Macromedia *Captivate.* Similar to live lectures, *Captivate* provides a series of written instructions in real time and demonstrates filling in the form. The examples were also presented in Web-pages to which students could later refer.

After each of the first two discussions, the instructor (first author) reviewed the summary notes/group AVDs, and gave each student short, written feedback. The purpose was to discourage "pseudo-integration" where students—in forming their final opinion—just picked the arguments they liked best and ignored counterarguments. Thus students were typically encouraged to "think deeper about the other side" and "not to ignore any important counterargument when performing your integration."

It also became apparent, after the first discussion, that students needed additional criteria for judging why arguments on one side might be stronger than the other. For the second and third discussions, we added a series of additional questions at the bottom of the AVD but before the integration section. The questions simplified the integration process by having students identify the two most important arguments on each side, judge the extensiveness of any advantages/disadvantages, weigh the values involved, and then evaluate whether the other arguments might change their final opinion, if at all. One question also asked if "there was a way of designing a solution so that opposing values could be realized?"

We coded notes and AVDs on: (a) number of arguments/counterarguments raised, (b) mention of the most important arguments/counterarguments in an organized way (*Coverage/Organization)*, (c) development of "it depends" final opinions that took into account both sides (*Compromises)*, (d) generation of creative solutions that realized advantages while minimizing disadvantage (*Creative Solutions*). We also examined whether students changed their opinion at some point during the procedure (*Change*). We randomly selected 22 discussions to double score; reliabilities were satisfactory (r = .87 and up).

We used the group as our level of analysis, because individual scores in a group were not statistically independent. Except for the first outcome variable, the variables were nominal. There were two sets of scores: one for the discussion notes, and one for the group AVDs in the experimental group. At the end of the study, students completed a confidential survey on the usefulness of AVDs.

Results

Overall, the AVDs significantly improved the richness of students' discussion, as measured by the number of different arguments/counterargument raised. The mean in the experimental group was 8.61 arguments and 8.89 counterarguments per group discussion, compared to 2.11 arguments and 2.09 counterarguments for the control group ($t(23) = 6.07$, $p < .001$).

In addition, the discussion notes of the experimental group contained significantly more compromises ($t(24) = 4.81$, $p < .001$). About two-thirds of the groups in the experimental group engaged in compromises ($M = 0.67$), almost none in the control group did so ($M = .06$). There was not, however, a significant difference in regards to creative solution ($t(34) = 1.28$, $p = .21$). Importantly, there was more opinion change in the experimental group ($M = .39$, $t(17) = 3.29$, $p < .01$, $M = 0$ for control).

There was not a significant difference in regards to *coverage* ($t(33) = 1.76$, $p = .087$). However, when the final group AVD's were examined, there was steady improvement in coverage (see Table 1). This finding suggests that the discussion stage did not contain a comprehensive coverage of all the important arguments, but enough arguments and counterarguments were nevertheless considered to induce compromising. The group AVD's may have added an additional element of coverage because the composer and elaborator were directed to include all important arguments and counterarguments.

Table 1: Experimental group means over time.

Time	Coverage	Compromise	Opinion change
1	1.00	0.67	0.17
2	1.40	1.20	0.80
3	1.75	1.00	0.50

Table 1 also shows a jump from Time 1 to Time 2 for *compromises* and *opinion change.* These differences could be due to topic or to the introduction of the additional AVD prompts at Time 2. Student survey comments indicated that the prompts helped them focus on counterarguments and compare arguments, resulting in more compromises and, in turn, opinion changes. (Using logistic regression, compromises did predict opinion change, odds ratio 4.16, $p < .05$.) Instructor feedback about not ignoring any important counterarguments and providing a balanced view could also account for the jumps.

In regards to the student survey ($N = 19$), comments were substantially positive. Students noted that the AVDs helped them focus on and evaluate the other side of the issue, and that the group AVDs helped them organize and synthesize various points. Of the 19 respondents, 13 (68%) made uniformly positive comments, and 5 (26%) made partially positive comments. Of these five, the greatest reservations related to the individual AVDs. A few students did not possess enough knowledge to think about counterarguments. Most students found the individual AVDs a useful brainstorming activity.

Discussion

With AVDs, students made more arguments/counterarguments, and synthesized them through suggesting compromises. The process also resulted in more opinion change. However, argument/counterargument integration was weak the first time students used AVDs. Students must be discouraged from engaging in *pseudo-integration*, where—in filling out the integration box—they just pick the argument that they think is strongest but counterarguments are ignored. We dealt with this problem through feedback and by including additional prompts. One surprising finding was that AVDs had little effect on generating creative solutions, which is at odds with the results from Nussbaum's (2006) essay study; perhaps the additional prompts that we added to the on-line version did not focus strongly enough on creative solutions. Future research should examine how to modify and streamline the additional prompts. Overall, however, AVDs show great promise for enhancing students' critical thinking and discussion skills.

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A Tale of Two Formats

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Abstract: The study examined one teacher's perspective on teaching the same material in an online format and in a face-to-face format. The instructor's reactions varied in part as a function of the topic being taught. Some topics were seemed to be suitable in either format whereas others were better in one format or the other. The instructor noted that the class who had face-to-face interaction changed dramatically when they began these modules.

Given the tremendous investment in computer technology in higher education during the past 20 years, it is of considerable interest to investigate students' learning outcomes when technology is an integral part of the teaching-learning process. Much of the research related to online courses has been devoted to demonstrating that students in a distance-learning course perform as well as those in a traditional course. Russell (2002) identified 355 studies that found no significant difference in student outcomes for traditional versus online instructional formats. However, Joy and Garcia (2002) conclude that much of the research is flawed. Among the problems they note are the failure to control for time on task, confounded treatments, selection problems, and small samples. In one study, for example, students who selected to take an online course in computer programming were older, less likely to be involved in a traditional undergraduate program, and worked more than those who chose the face-to-face version of the same course (Dutton, Dutton, & Perry, 2002). Comparisons of outcomes in the two versions of the course were confounded by the differences in the student populations involved.

Other studies that compared learning in traditional, face-to-face, classroom-based ("lecture") college courses with learning in computer-based, distance education ("Web") courses have yielded inconsistent results. The mixed pattern of learning outcomes may stem from individual differences in ability, attitude, or personality associated with selection effects and/or a failure to have equivalent levels of structure across course formats (Maki & Maki, 2002). Online courses may include proven instructional treatments that are not present in the comparison instruction. For example, in Maki and Maki's comparison of web-based and lecture-based instruction in psychology, students using the web-based instruction were required to complete mastery quizzes on the web and were provided with immediate feedback. The students in the lecture class did not have these opportunities for practice testing or feedback. Thus, it is difficult to separate out the effects of the format from the effects of particular instructional activities.

Relatively little attention has been paid, however, to the experience of the instructor in an online format or in a face-to-face format. The present study examined the experiences of an instructor who taught the same course content and used the same activities in two different formats. We used the same instructional activities in two different formats. Half of the students completed the entire semester in a traditional format. The other half completed the first half of the semester in the traditional format and the second half of the semester using Web-based curricula materials and assignments ("hybrid" format).

Method

Participants

The course was a junior level educational psychology course. The instructor, Patti, taught two sections of the course, each with 35 students. Patti was a certified classroom teacher and had taught fourth grade for four years. She had also served as a supervisor for student teaching and had a master's degree in Educational Administration.

Materials

All students (irrespective of course format) had access to a course website on which outlines of assigned readings, practice quizzes, links to related materials (e.g., research articles, newspaper reports, activities, organizations) were available. The senior members of the research team also designed special curricula materials (five units, 1 per week) to be used for students after the midterm. The units were based on key instructional problems that teachers face in classrooms and were intended to promote students' integration of theory and practical issues. These materials were to be used in either the hybrid sections (online) or by the regular sections (in class). For example, a series of videotape segments of cooperative learning in classrooms was made available online for those in the hybrid section and the same videosegments were shown in the regular classrooms.

Procedure

Student teams were formed during the first seven weeks of the course and these teams continued throughout the semester. The groups shared ideas, engaged in discussions, completed exercises, and commented on one another's work. During the first 7 weeks of the course, the emphasis was on teaching basic concepts related to educational psychology and providing the theoretical background for these concepts. The materials available on the course websites supported this function. To facilitate a true comparison of the effect of the hybrid format and regular class, it was important that all students have exposure and competency with technology. The instruction in all of the sections involved the use of web-based instruction as demonstrations in class but also as homework assignments in the initial course period.

After the midterm, the focus was on integrating theory and practice. In the hybrid version of the course, this was accomplished online while the traditional class continued to meet. In the traditional classroom, instructors introduced the content and students worked in small groups and engaged in discussions, produced materials, commented on one another's work. In the hybrid sections, students completed the same activities as those completed by students in the traditional classroom but did so asynchronously. The key differences between the two formats were in the timing of students' contributions and the potential in the hybrid sections to revisit materials as needed. All participants took the same examinations constructed by a member of the team who did not teach a section of the course.

Patti taught the same content and used the same activities in the two sections of the class (online, face-to-face). Each week, the first author interviewed Patti about her experiences in teaching the two versions of the class. There were a total of six interviews, each lasting approximately 30 minutes. Five of the interviews related to specific content taught and the sixth interview was a review of the entire experience. The interviews were transcribed and analyzed using NVIVO qualitative software.

Results

Reaction to the Online Format

Patti had many positive comments to share about the online format. Features of Webct such as the ability to track the amount of time students' contributed to the online discussions allowed Patti to quantify students' participation. Patti felt the students were engaged and provided detailed, well- supported answers. Another positive feature of the online environment was students were able to view the video as often as needed. Not only did this give students more time to view each clip, it also relieved any pressure to "get it all" the first time.

Being able to re-watch the video clips also raised the level of accuracy of students' responses. By having the video clips available online, students were able to re-watch the videos to check the accuracy of their own as well as other students' responses. This improved the overall quality of the students work. Finally students were able to use the Internet as a resource to research relevant background information. This improved the quality of their responses. While Patti had many positive comments about the online format, over the duration of the course, she became overburdened by the amount of time the online class required. Patti spent hours responding to individual as well as group responses.

Another limitation of the online environment was the lack of immediate reaction. Essentially students had an entire week to post their responses. This created periods of little posting and response to others students' critiques. Students' procrastination limited the interaction between the group members and produced rushed work.

Reaction to the In-Class Format

When asked about the positive features of the in class format, Patti elaborated on the instantaneous interaction between her and the students and to the material. Patti was also impressed by the amount of work students were able to produce given the small number of students in each group coupled with the limited amount of time they were given to complete the assignment. Patti noticed a dramatic change occur within the in-class cohort between the first two sessions. Attendance increased, the students were prepared for class and were applying the material at a deeper level. Overall Patti felt more connected to the students and enthusiastic about working with the groups. Thus increased attendance and participation led to an overall higher interaction between the students. This fueled more productive and well-informed discussions. The in class format allowed Patti to respond instantly to concerns and questions and guide the discussions in the appropriate direction. Patti was pleased at how the lesson planning activity progressed in the in class format. Students' actively participated and provided detailed, well-supported responses. Patti also enjoyed the opportunity to give immediate feedback to students' questions and clear up any misconceptions that may arise.

It is clear that Patti values learning and enjoyed the opportunity to clear up misconceptions immediately and be a part of students interacting. She even began posting feedback for the in class group on WebCt to allow for more discussion time in class. Patti is truly enjoying the classroom atmosphere. Patti feels the interaction of the class will help students on the essay part of the final exam. She asserted that she enjoyed having the opportunity to lecture some of the material to the in-class group, which she stated was a real benefit. Patti also acknowledged that the group lessons and assessment tasks were easier to create in class, again due to immediate reactions.

When asked about the limitations of the in class format, Patti expressed disappointed by the lack of information regarding time students' contributed to the material. WebCt allowed Patti to track each students' time and contribution to the group summaries, while the nature of the in class format made it difficult to determine who was contributing what. In other words, because students' efforts weren't easily identifiable and measurable it was difficult to assess who was doing the work. Patti also felt that the pressure to complete all the activities with the 90-minute class period was a limitation of the in class format. Students in the in class format were not able to view the clips multiple times for accuracy like the online group. Finally, Patti commented on how difficult it is to know whether students have read before class and are prepared to contribute to the assignments. She also elaborated that there was insufficient time to complete all the activities effectively.

Discussion

Patti's reactions to the two formats varied in part as a function of the topic being taught. She felt that some topics (the Pupil Assistance Committee exercise) worked better in class because of the utility of the spontaneous interaction of classmates to one another's judgments of the video they saw. The structure of the in class format lends itself to active discussion of the video clips. She felt it was difficult to have that interaction in the online format. Patti felt the mood of the online group was rejuvenated from the lesson planning activity. Students enjoyed viewing and critiquing other groups' work. Patti noticed that when students enjoyed the activity they provided more detailed and timely responses on Webct. Patti admits that at first she was hesitant of the dedication of the in class group, but witnessed a dramatic difference in the students performance from when they began these modules. In fact, at the start of this project Patti was concerned with her lack of control over the in class group, but as time progressed, she felt that she had more control with the in-class group then over the online group because she could guide the discussions and answer students questions as they arise. She also felt that the online group lacked the social interaction that was fueling the progress of the in class group. Patti enjoyed how the assessment activity worked with the online group. They had a higher quality of responses, used the text to support their ideas, spent more time with the material, and had the benefit of being able to re-watch the videos a second time. The results will be further discussed at the conference.

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The impact of 3-D based group interactions in an on-line problem-based learning environment

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Abstract: The purpose of this article is to present the results of a study conducted to investigate how the attributes of 3-D technology influence the group interactions toward problem solutions and how it impacts the instructional practice in on-line PBL. Results suggested that the attributes of 3-D technology, if used properly, would promote students' social presence and their meta-cognitive awareness.

Introduction

One of the recent trends in research on cyberinfrastructure focuses on 3-D based on-line communities where the emphasis is to promote community participants' social presence and collaborative inquiry. (CRA, 2005; Dalgarno, 2002; Dickey 2005; Jones, 2004; Jones, Morales, & Knezek, 2005). Learners in such environments often have the opportunities to experience real lifelike social interaction while at the same time, engaging in meaningful learning activities. For instance, Barab et al. (2005) created a 3-D multi-user virtual environment (3-D MUVE), *Quest Atlantis*, to support participant-centered collaborative inquiry by providing interactive quests and social games through animated avatars and virtual scenes. The resulting 3-D real life interaction metaphor, pedagogical driven quests, and on-line collaborative features incorporated in this 3-D MUVE provide learners and instructors with opportunities for community building and for engaging in meaningful educational activities.

The characteristics of collaborative inquiry and animated social interaction appear to make them ideal for problem or inquiry based learning (PBL). PBL is structured around problems or challenges that the learner is motivated to solve. There is an emphasis on the process of learning rather than the acquisition of facts. PBL as an instructional strategy is increasingly being used for on-line learning (Garrison & Anderson, 2003; Orrill, 2002; Uribe, Klein, & Sullivan, 2003)

The purpose of this study was to investigate the effects of 3-D based on-line group interaction in an on-line problem-based learning environment from the lens of Garrison and Anderson's (2003) community of inquiry model which aims to build a cohesive on-line community of participants and instructors. The model's main components are cognitive presence, social presence, and teaching presence. The community of inquiry model helps us understand students' higher levels of thinking during online collaborative learning by providing indicators for interpreting outcomes of online discussions.

The element of cognitive presence within the community of inquiry model contains four main categories. These are: triggering event; exploration; integration; and resolution. In the PBL process, these categories may support findings related to problem identification, problem analysis, and performance presentation, since PBL is an instructional strategy that engages learners in critical thinking. The element of social presence within the community of inquiry model has three main categories. These include affective, open communication, and group cohesion. In PBL, these categories of social presence may help to support data related to all the PBL stages of group formation, problem identification, problem analysis, and performance presentation, since PBL as an instructional method is intended to engage learners in collaborative problem solving. The final element of the community of inquiry model, teaching presence, is broken down into the categories of design and organization, facilitating discourse, and direct instruction. In PBL, the indicators from this element may help to support findings related to the role of the facilitator.

Garrison and Anderson (2003) suggest that PBL activities are a part of assessment activities which could be supported by the community of inquiry framework. However, for PBL activities to be successful in online learning, Garrison and Anderson state that "since most PBL activities are structured to allow group investigating, the needs for supporting group synchronization, document management, discussion, and task assignment must be supported"

(p. 100). If these design concerns are taken into account, 3-D MUVEs may be a suitable platform for collaborative online PBL group activities.

Research Questions: How do 3-D attributes such as avatars and bubble dialogue chat boxes (LDHRG, 1992) impact students' social interaction and presence at the early stage of problem solving activity (i.e., group formation and problem analysis) and how does this interaction impact their later stage of problem solving activity (i.e., action planning and presentation)?

Methods

Exploratory Case Study methodology – Case studies "identify problems of practice" by providing a "holistic account" of the phenomenon under investigation (Merriam 1998; Yin, 1994). The study used online observation, interviews and transcript analysis to collect data.

Participants and Procedure

The participants in this study consisted of 2 groups of 8 graduate students in a 500-level, three-credit hour introductory instructional technology course at a mid-western university.

The 3-D virtual environment used in this study is called *ActiveWorlds*®, an online virtual community where users can appear as a 3-D based "avatar", that is, a graphical representation of the user (Dickey, 2005). Participants travel (either by foot or time travel) to various virtual regions, and interact socially with other avatars. Participation in the online PBL activity using *ActiveWorlds*® was entirely voluntary and the participants who took part in this study gave consent to use *ActiveWorlds*® for their online group discussion. The course instructor divided the students into 2 groups.

Participants who agreed to use *ActiveWorlds*® were asked to use the system over the course of four weeks, as often as they desired. A follow-up group interview occurred after the four week period to explore the participants' willingness and ability to use the system and the system's potential to enhance their problem-solving performance. The focus group discussion was transcribed and coded into 3 three thematic findings. Transcripts generated form the participants' *ActiveWorlds*® interactions were analyzed and used to reflect and validate the interview findings. Interviews with the course instructor were also conducted to elicit the instructor's perspectives and outcomes of using *ActiveWorlds*® as a tool to support on-line collaborative inquiry.

Findings

1. The 3-D based communication metaphor enhanced the students' on-line social interaction experience and promoted better on-task discussion at the beginning of the problem solving process.

2. The embedded bubble chat box along with the 3-D scene provide an authentic and non-linear collaborative environment allowing students to better organize discussions and respond to questions prompted. Therefore students have a greater opportunity to reflect on the issues and problem to be solved.

3. Potential barriers to using the 3-D virtual environment:
While all subjects had a positive reaction to using Active Worlds, they expressed concerns about the use of the system's technical features. Its limited functionality (i.e., avatar gestures, sitting, and so on) caused the avatar to be a minimally used system function. Similarly, some students found the background sounds to be distracting while some reported that aimless movement by their colleagues sidetracked their discussion.

Discussion

The online experience may become realistic in the sense that it mimics a face-to-face experience whereby learners interact with other avatars synchronously online. The focus group data revealed that the bubble dialogue chat box allowed some learners to reflect on their problem-solving process.

<u>Sounds, animations, colors, movement etc</u>

Sounds, movement in the 3-D environment may overwhelm learners as they interact in the 3-D environment.

Adult Learners and the design of the 3-D environment

If an online collaborative activity is intended for adult learners, designers of 3-D MUVEs should take adult learning principles into consideration so as to make the online experience meaningful for adult learners.

Conclusion

The study findings suggested that 3-D virtual environment have the potential to become a usable collaborative tool for the participants. Areas for improvement: (1) Provide instruction and feedback so learners can fully exploit more advanced system features (e.g., provide participants prompts or wizard function), (2) a facilitator to guide the process of the collaborative inquiry to ensure all voices are heard, and (3) a problem support repository either embedded in or exist outside of the 3-D virtual environment to allow learners to access, track, and present their problem analyses and ideas solving during the discussion.

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Examining the Dual Function of Computational Technology on the Conception of Mathematical Proof

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Abstract: In this paper, I examine how the availability of a certain technology and new ideas about the nature of learning operate as a factor to suggest a novel understanding about a crucial mathematical concept: mathematical proof. I characterize the resulting conception for ideal mathematical proof activity combining two fundamentally different ways of knowing: *a posteriori* (or experimental/empirical) and *a priori* (or deductive/propositional). Obviously, such conception of proving is/will be central in designing proof tasks, thus shaping the mathematical discourse around proof within classrooms. Whether one considers participation within such discourse is simply an aid or tantamount to thinking, identifying the character of this discourse appears to be essential in order to examine the interrelationships between what is social and what is individual.

Salomon (1998) argues that technology serves a dual function resulting with a reciprocal relationship between technology and our understanding of human learning. On the one hand, the use (and the design) of technologies are informed and guided by the theories of learning. On the other hand, affordances provided by new technologies offer novel learning experiences, which in turn compels us to reconsider our conceptions about learning. In this paper, I aim to draw attention to yet another mechanism between technology, society, and human mind within the context of mathematical proof and new computer tools.

Traditionally, proving activity has often been conceptualized along one dimension: Providing a *deductive* argument. That is, students are either presented or asked to write rigorous logical arguments to establish the truth of the mathematical theorems. This represents *a priori* (Kant, trans. 1998) way of knowing, since one reaches a *true* conclusion by starting with a set of axioms, the building blocks of any mathematical structure, and applying the rules of logic to those axioms. Empirical or *a posteriori* (ibid.) ways of knowings are almost always left out within proving activity. I argue that the interaction between two major forces challenges such conception of proving.

One of the forces to challenge the conception of students' proving activity as a merely deductive experience is the recent mathematics education reform movement led by the NCTM (1989, 2000). In NCTM documents, "'[k]nowing' mathematics is 'doing' mathematics. A person gathers, discovers, or creates knowledge in the course of some activity having a purpose" (NCTM, 1989, p. 7). This process and meaning-centered perspective has led researchers to think about what makes proof *meaningful* and thus to reexamine the nature of mathematicians' proving activity.

As a result, there is a growing emphasis on the role of empirical explorations in mathematics education (Hoyles, 1997). While earlier conceptions of proof excluded empirical ways of knowing within proving activity, new ideas about the nature of learning have proposed the opposite. Researchers have come to believe that exploration/experimentation of mathematical ideas is an important ingredient of proving, for it reflects the work of expert mathematicians, gives students the opportunity to work from their own intuitions and investigations, and thus potentially makes proving more meaningful and accessible (Boero, 1999; Edwards, 1997; Reiss & Renkl, 2002).

The realization of the aforementioned vision of proving has been enabled by the immediate availability of a very powerful set of computer tools, namely dynamic geometry software (DGS), in classrooms. DGS materializes the vision described above, due to its most defining feature: dragging. That is, when the elements of a drawing are moved, this feature allows the construction to respond dynamically to the altered conditions (Goldenberg & Cuoco, 1998) by maintaining the invariant. This aspect of DGS facilitates conjecturing and more inductive approaches to geometric knowledge, as students can reason about the generality of their hypotheses for several cases (Kaput, 1992).

However, as much as DGS attracts great interest, concerns have been raised that students using DGS could be misconceptualizing the nature of mathematical truth; that is, coming to believe that a confirmation of a conjecture for several cases would secure its truth (Allen, 1996; Chazan, 1993b). As conviction can be obtained easily by dragging, DGS environments may prevent students from understanding the need and function of proof (Hadas, Hershkowitz, & Schwarz, 2000).

Despite these concerns, however, other researchers have maintained their position arguing that there is no tension between proof and empirical exploration (de Villiers, 1997, 1998; Hoyles & Jones, 1998). Researchers view working with DGS as an opportunity to emphasize the *explanation* function of proof (that is, providing insight into why the theorem is true) as a viable alternative to the notion of proof whose function has been chiefly verification, as in the traditional teaching approach (de Villiers, 2003; Hanna, 2000). Further attempts also have been made to show with empirical studies that DGS could be a useful tool to teach proof (Hadas et al., 2000; Healy & Hoyles, 2001; Jones, 2000; Mariotti, 2000, 2001; Marrades & Gutierrez, 2000).

This interaction between the ideas of reform and the immediate availability of computational technology in classrooms leads us to a notion of proof that encompasses both empirical and deductive ways of knowing. Moreover, they are considered complementary and reinforcing each other. However this does not suggest that exploration and formal proof are separate activities and mediated by different tools. Research shows that computational technology also problematizes the discrete positioning of the two different ways of knowing. In other words, there is evidence to think against the idea that one can only make exploration phase efficient with DGS and students turn to paper and pencil in order to give deductive arguments for their conjectures.

In mathematics education research, there is a growing recognition of the "reorganizer" (Pea, 1985) nature of DGS. That is, several authors point out that DGS is not simply making the task more efficient, rather it fundamentally changes the task (Healy & Hoyles, 2001; Jones, 2000; Lerman, 2001). Within the DGS learning environment, "[t]he computer is more than a mediating bridge, as its function cannot be simply reduced to a learning aid – to be discarded after the concepts and procedures have been acquired" (Holzl, 2001, p. 81). According to Scher (1999), DGS is also exerting its influence on the proving activity. He criticizes the body of work that limits DGS use to only explorations. For him, the boundary between deductive reasoning and dynamic geometry becomes increasingly blurred.

Referencing Salomon (1998), in this paper, my purpose was to highlight how the dialectic between two forces has resulted with a new conception for mathematical proof. It appears that the way educators understand and think about proof has a new meaning, resulting from a mutual relationship between the ideas of reform and the availability of computational technology. Both deductive/propositional and empirical/experimental ways of knowings are equally incorporated in this revised conception. Moreover, computational technology also compels us to rethink about the distinction between exploration and deductive proof. This conception does and will shape the mathematical *discourse* within which students are expected to participate. And the emerging notion of mathematical proof discussed in this paper proposes a layer of understanding regarding the mathematical discourse around proof.

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Complex Network Theory Approach to the Assessment on Collective Knowledge Advancement through Scientific Discourse in CSCL

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Abstract: This study discusses the possibility of the integrated analytic approach to discourse in CSCL by the combination of macro network analysis and micro analysis of argument on students' written discourse. Although studies have established fine-grained analytic approaches to discourse or argumentation in CSCL environments, we still have difficulty with evaluating collective knowledge advancement. The *Complex Network Theory* would be a promising approach to challenging this difficulty. We can visualize a variety of network structures with identifying ideas as *nodes*, and co-presence of words as *links*. Several indices numerically inform us how a target network is structured. In this paper, we report our attempt to describe how the network of ideas represented in discourse is structured in CSCL environments and its relation to the network structure analysis.

Background and Research Purposes

Although the development of argument analysis in the learning sciences provides us with fine-grained information on cognitive activity by individual learners (e.g., Kelly, & Takao, 2002; Sandoval, & Millwood, 2005), we still do not have tools to evaluate learners' collective knowledge advancement. The assessment of collective knowledge advancement is crucial with two reasons. One comes from the perspective of *summative assessment* that the combination of discourse analysis at the individual learner's level and collective or structural analysis of ideas gives us richer interpretation of individual learner's cognitive performance. The analysis of how each individual learner contributes to collective knowledge advancement is an important measure of the knowledge advancement through collaborative learning. Another reason comes from the perspective of *informative assessment*. If we figure out how each learner is contributing to the collective knowledge advancement in the community such as a classroom, we can suggest each learner what ideas they should know or contribute to in their next stage of learning.

We propose an analytic approach to achieving the dynamic assessment on students' collective knowledge advancement, the network structure analysis based on the *complex network theory* (Barabási, Albert, & Jeong, 1999; Watts, 1999; Watts, & Strogatz, 1998). The *complex network theory* is an analytic approach to describing a variety of network structures developed based on statistical physics, and several important features of the network structures around us were discovered (i.e., the Small World, the Scale-Free, etc.). Some of recent studies were focused on the issue of whether the same principles could be applied to the development of the computer-network communication. For instance, one study by a Japanese research group (Tagawa, Yasutake, Yamakawa, & Inoue, 2006) attempted to describe remarkable features of computer-mediated communication by university students with WebCT. Although the network structure analysis would give us important resources to evaluate students' collective knowledge advancement, we have not yet known how we can utilize the indices from the network structure analysis in evaluating students' knowledge advancement in collective situation. In this study, we attempt to find answer to this research question by comparing results from both fine-grained and network structure analysis on the same students' discourse in a CSCL context.

Methodology

Target Group of Students

Forty-one fifth grade students (21 females, and 20 males) at a Japanese elementary school were engaged in their collaborative learning on genetically modified foods by using Knowledge Forum®. They discussed whether they should develop GM crops or not and why based on their understanding of GM foods (Oshima, et al., 2005). We analyzed their written discourse in the final phase of learning through the two approaches.

Individual Analysis of Written Discourse

Written discourse in each report was analyzed from the perspective of the argument structure and the epistemic operation (Oshima, Oshima, & Knowledge Forum® Japan Research Group, 2006). In the argument structure analysis, we referred to the simplified framework of Toulmin's (1958) argument structure such as *Data*, *Reasoning*, *Claim, and Rebuttal*. Each written discourse was evaluated with whether each argument component was present. In further analysis of epistemic operations in written discourse, the cognitive levels of the two components (i.e., *Data*, and *Reasoning*) were evaluated by referring to the rubric developed in other studies (e.g., Sandoval, & Millwood, 2005). Two trained undergraduate students independently involved in the evaluation procedure. The inter-rater agreement was over .80. The disagreement was resolved through discussion with the first author.

Network Structure Analysis

Each discourse was decomposed into paragraphs as minimum units of ideas, and each paragraph was further decomposed into morpheme words through the software application of Japanese language morphological analysis. The same procedure was applied to discourse in teaching documents on the genetically modified foods that we created under a domain expert's supervision. We depicted nouns that appeared in both corpuses. Based on the list of noun words, we conducted the complex network structure analysis on the both corpuses by the software called *Pajek*. *Pajek* is a network structure analysis application that provides us with basic descriptions of each node (word in this case) and statistical indices, *clustering coefficient* and *betweeness centrality*. The *clustering coefficient* is a measure in describing network structures. We omit its mathematical explanation here. In short, the coefficient informs us how each node (word in this case) contributes to the development of clustering structures in the network. We can describe how the target network is composed of idea clusters and how powerful the central ideas are in structuring the network. The *betweeness centrality* is another measure that manifests how central each node is in the network structure or clusters. With these two measures, we can describe network structure of ideas learners reported in their written discourse from the perspectives of how their ideas are linked to one another as groups, and which word plays important roles to create clusters of ideas. In this study, we used the network structure of the document we created as the benchmark of idea network. Later, we compared network structures of students' discourse with the benchmark structure to examine how scientifically appropriate the network structure of ideas in students' discourse is.

Stepwise Network Structure Analysis

For examining the relationship between measures from the discourse analysis and the network structure analysis, we conducted what we call *stepwise network structure analysis*. The stepwise network structure analysis is the procedure that compares the network structure of nodes from total reports with that excluding a target single report for examining its contribution to the total network structure. Our assumption was that a network structure would be significantly changed by excluding cognitively important discourse. We detected several reports that produced crucial changes in the two coefficients of ten most important words in the corpus. Then, we attempted to characterize discourses evaluated as important in idea network structures by using their argument structures of written discourse.

Results and Discussion

First, we conducted the network structure analysis on the two corpuses of discourse by students and researchers. The number of nodes was 101. The mean *clustering coefficients* across all nodes were 0.769713 for students' and 0.760392 for researchers'. The mean *betweeness centralities* were 0.009211 and 0.007735, respectively. If we looked at ten most influential words in structures, only three were appeared in the both lists. In sum, the network of ideas by students' discourse and researchers' discourse were structurally similar, but cognitively different. We further conducted network structure analyses by separating the discourse by positive and negative opinions. The differences in the structures were remarkable (Figure 1). The mean *clustering coefficients* were 0.811 in positive opinion and 0.811 in negative opinion. The *betweeness centralities* were 0.018 in positive opinion and 0.011 in negative opinion. Results manifest that network structures of students' discourse at each side were more different from the researchers' than students' total structure. Based on results, we think that students' idea network structure came to be closer to the researchers' as their learning went on, but students focused their attention to limited range of learning materials.

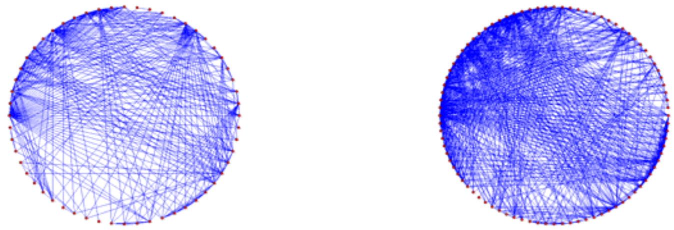

Figure 1. The Network Structures Based on Students' Discourse with Positive (left) or Negative (right) Opinions.

Second, we compared students' discourses detected as strongly influential to their idea network structure with those evaluated as robust in the argument structure analysis. We found no systematic relation between the two results of analyses, but concluded that the two analyses provides us with more fine-grained characteristics by covering different perspectives of students' knowledge advancement in CSCL environments. Discourses highly evaluated by the both analyses are considered to play central roles in their collective knowledge advancement and have robust argument structure. Therefore, instructors can use those as benchmarks of how students' knowledge advancement is evolving. Discourses highly evaluated by the argument analysis but not by the network structure analysis were further divided into two categories. One category included discourse showing ideas appeared in other notes. Idea networks in these discourses can be easily replaced by other discourse and they do not influence the network structure at all. Instructors should suggest authors to merge their reports in one integrated note and further think of its relation to other notes. The other type of discourse was discussing very local ideas so that they created small clusters in the network and no links to other ideas. The instructor can suggest students to think of how their ideas should be related to others' ideas. Particularly, the benchmark notes that are highly rated by both analyses would be good for them to see. The last category was discourses highly evaluated by the network analyses but not by the argument analysis. It may be difficult for other learners to comprehend ideas appeared in this type of discourse because the argument structure is not clear enough. If instructor thinks that ideas in the discourse are valuable to further develop in collaboration with other learners, s/he has to help authors create more robust structures of arguments.

Endnotes

(1) Knowledge Forum® Japan Research Group in conducting this study consisted of the following members: Shigenori Inagaki, Isao Murayama, Makiko Takenaka, Etsuji Yamaguchi, Hayashi Nakayama, Tomokazu Yamamoto, Masaji Fujimoto, YukoTakeshita.

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Appropriation of a Graphical Shared Workspace: The Learner-Tool Connection

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Abstract: The influence that a CSCL tool has on a group of learners depends on how the tool is appropriated. Different ways of appropriating a tool may lead to different effects on the way learners interact and carry out their task. To study the process of tool appropriation we apply an analytical distinction between interaction with the tool and interaction via the tool.

Introduction

CSCL tools are designed on basis of expectations about how collaboration within a dyad or a group proceeds, and how this collaboration could be enhanced through use of technology. However, learners do not necessarily use a tool in accordance with the expectations of the designers. When learners are presented with a new tool they have to appropriate it. Learners appropriate a tool by ‘adapting’ it in a goal-directed activity. Hereto the learners have to make sense of the properties of the tool, and find ‘a way of doing’ to carry out their task. Group members have to explore its possibilities and monitor the consequences of their actions. In the case of collaboration, group members have to coordinate this effort. The group has to arrive at some kind of agreement on how to operate the tool. For example, they have to attain a shared understanding of the symbols that are displayed in the user-interface. And they have to find a common strategy to manipulate the user-interface to achieve an outcome. The affordances of tools are appropriated in sometimes unexpected ways (Dwyer & Suthers, 2005). Different ways of appropriating a tool may lead to different effects on the way learners interact and carry out their task (Overdijk & Van Diggelen, 2007).

Tool-mediated interaction

Scholars within the CSCL community have argued that tools reflect information about their use and effect through the way they interface with the user. The user-interface makes affordances available that provide certain opportunities for action. The notion of ‘affordance’ has been proposed as an instrument to analyse the ‘effects’ and ‘constraints’ of a technology (e.g. Suthers, 2006). The theory of affordances (Gibson, 1979) adopts a relational approach towards the connection between the learner and the tool. The concept of ‘affordance’ proclaims that learner and tool are mutually constitutive and inseparable (Gibson, 1979). This makes a conceptualization of the effects and constraints of a technological tool problematic, because the phenomenon of tool-mediated interaction can not be attributed to the learner or to the tool. To overcome the inseparability between learner and tool we propose the application of an analytical distinction between interaction of learners *with* the tool and interaction of learners with each other *via* the tool. The interaction of a learner *with* the tool can result in a number of tool-shaped actions. These tool-shaped actions can lead to tool-mediated interaction between learners *via* the tool. This analytical distinction helps to analyze (1) how interaction with the features of the tool shapes the learners’ actions, and (2) how this interaction gives rise to specific patterns of interaction between the learners.

A graphical, shared workspace

To illustrate our concept we present a brief example of an analysis of tool appropriation. The example focuses on one group of learners (N=3), and is taken from a case-study about a specific type of CSCL tool: a graphical, shared workspace. This tool was deployed to support an argumentative discussion within the group (For a full report on this study, see: Overdijk & Van Diggelen, 2007). Basically, the shared workspace tool consists of a drawing space and a graphical notation system that supports specific kinds of communicative acts. The user interface of the tool “prompts” a specific set of contribution cards and makes these contributions salient to the users. Learners can choose a contribution card from the notation system, and add a textual message to it. They can use a comment window to give a more detailed account of their ideas or thoughts. Once the contribution is placed in the drawing space, it can be moved through the drawing space and related to other contributions through the use of links. Learners can contribute to the workspace simultaneously. In this way, learners can collaboratively construct argumentation in form of a diagram.

Method

The content and structure of the contribution cards in the drawing space changes continuously over the course of the interaction process. All possible manipulations – like changing the location of a card, or adding of a link – have to be taken into account. The replay function of the tool allows us to reconstruct the interaction process. It captures all 'basic actions' that take place in the tool, resulting in a frame-by-frame representation of actions. The replay is transcribed into a spreadsheet that includes the time-line, all basic actions, the students responsible for the action, and the textual content of the contribution. This enables us to provide a detailed account of the interaction process. To describe the interaction process we apply an analytical distinction between the interaction with the tool and the interaction via the tool. The analytical distinction leads us to distinguish two levels of analysis. First we address the learners' interactions with the tool, then we attend to the interactions between learners via the tool.

Interacting with the tool

In order to submit a contribution to the drawing space, multiple interactions with the tool are required. A contribution is composed of several 'basic actions'. First, one has to select a notation card. The card can be placed in the drawing space by clicking on a location of choice. The selected card appears and can be further manipulated. A text can be written in the title space of the card by clicking on it. When the card is double-clicked, a separate comment window appears. In this window a more elaborated textual statement can be added to the card. Furthermore, the card can be resized, a link can be added between two cards, and the card can be moved through the drawing space.

We calculated the relative frequency of each basic action for our example group. The basic actions that occurred most frequently were adding a card to the workspace (15%), adding a title (15%) and link (23%), and moving the card through the workspace (42%). We used the software Sigmaplot® to generate a graphical representation of the frequency and distribution of each basic action over a time-line. Figure 1 shows that of our example group. Three basic actions are displayed: adding a title to a card, moving a card, and adding a link between two cards (Figure 1).

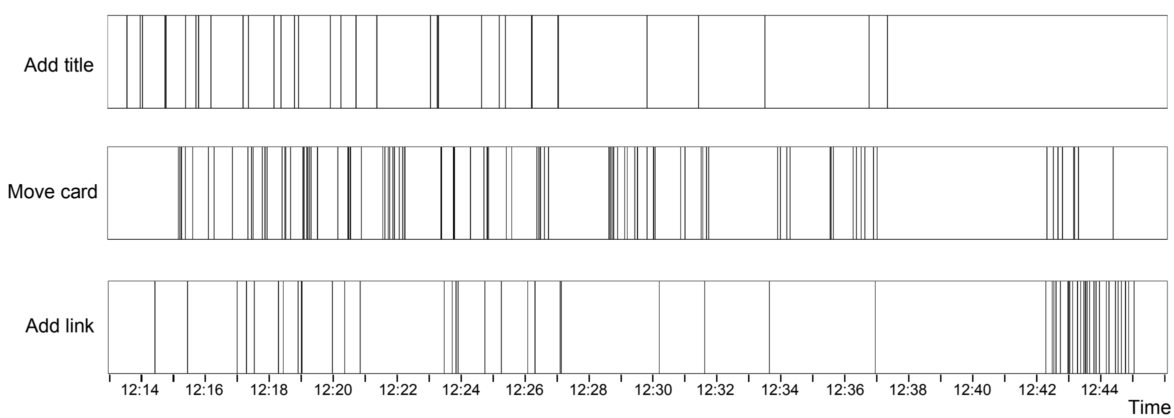

Figure 1. Basic actions in the tool.

By looking at the basic actions in the tool we can start to describe the interaction process. For example, we learn that the members of the group submitted 7 contributions before they started to move their cards through the drawing space. We can also see that the group members performed a lot of moving actions throughout their discussion, and that near the end of the discussion, they performed quite some moving and a lot of linking actions.

Interacting via the tool

In order to examine the interaction process in further detail we now turn to the level of interaction via the tool. We analyzed the contributions in the drawing area by unravelling them into separate 'discussion lines'. A discussion line is a string of contributions that are placed in adjacency by one or more learners. The learners made use of two principles to place contributions in adjacency in the drawing space: linking and spatially grouping of contributions. By moving cards through the drawing space, students could change the position of a card and spatially group cards. The application of these two principles was used to distil separate discussion lines from the diagram in the drawing space. Some of the diagrams display a number of floating contributions that are not clearly associated to any other contribution in the diagram. These were left out of this part of the analysis.

The figure below depicts the contribution cards of our example group organized in discussion lines, and represented horizontally in temporal order (Figure 2). The straight horizontal lines represent a demarcation of two separate discussion lines. Our example group constructed four discussion lines (1.1, 1.2, 1.3 and 1.4). Each group member is represented with a shape: a circle, a triangle or a square. The connecting lines between the contribution cards of a particular group member indicate that member's 'jumps' between discussion lines, i.e. spatial behavior in the drawing space.

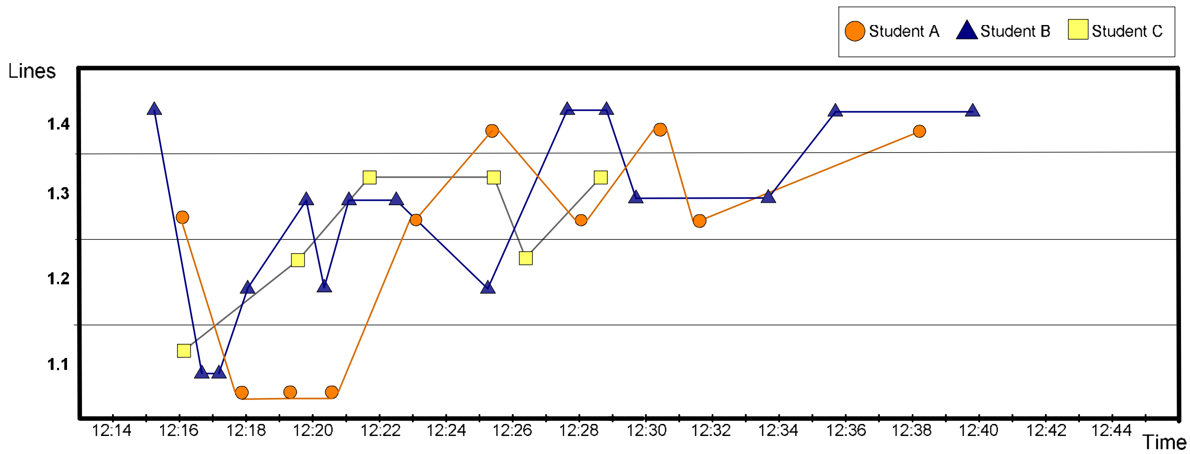

Figure 2. Discussion lines and spatial behaviour in the drawing space.

One can see that all members of this group submitted an opening statement at the beginning of the discussion, and that eventually each of these statements evolved into a discussion line. Figure 2 also indicates that the members in this group participated in multiple discussion lines. For example, student C places a contribution in line 1.1, then moves to line 1.2 and subsequently to 1.3. Finally, this part of the analysis reveals that the learners interacted with each other at a high-pace, resulting in a complex pattern of spatial behavior in the drawing space.

Discussion

The distinction between interaction with the tool and interaction via the tool provides valuable information about the process of tool-appropriation. Micro-level analysis of basic actions in the tool reveals phenomena that would otherwise remain unnoticed. These phenomena contribute to an explanation of the tool-mediated interactions between learners. For example, in their interaction with the tool learners make certain choices that influence the interaction via the tool (Overdijk & Van Diggelen, 2007). The mechanism of tool appropriation can be described as a result of interdependent tool-shaped actions and tool-mediated interaction. To unravel this mechanism, one has to study both levels.

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Expressive Pen-Based Interfaces for Math Education

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Abstract: Mathematics students almost exclusively use pencil and paper—that is, they learn without computational support. In this research, 16 high school students varying in ability from low to high participated in a comparative assessment of geometry problem solving using: (1) pencil and paper, (2) an Anoto-based digital stylus and paper interface, (3) a pen tablet interface, and (4) a graphical tablet interface. Cognitive Load Theory correctly predicted that as interfaces departed more from familiar work practice, students experienced greater cognitive load and corresponding reductions in their expressive fluency and planning. The results of this study indicate that students' communication patterns and meta-cognitive control can be enhanced by pen-based interfaces during math problem solving activities. In addition, low-performing students do not automatically reap the same advantage as high performers when new interface tools are introduced, which means intervention may be required to avoid expanding the achievement gap between groups unless intervention is undertaken.

Introduction

Although current graphical interfaces can support routine tasks like word processing and e-mail, they frequently fail to support more complex problem solving tasks in domains such as mathematics. In fact, current work practice for mathematics education almost exclusively involves pencil and paper, or learning without computational support. One reason for this is that modern interfaces do not support user input fluency in different representational systems (e.g., linguistic, numeric, symbolic, and diagrammatic), or flexible translation among them (e.g., from word problems and diagrams to algebraic formulas). Whereas graphical interfaces provide good support for linguistic and numeric content, symbolic and diagrammatic input are poorly supported—or not supported at all. A second reason is that traditional graphical interfaces are heavily laden with potentially distracting features. Thirdly, they typically depart from existing work practice. In the present paper, we focus on evaluating alternative interfaces that transparently mimic students' existing work practice, such that cognitive load is minimized during complex geometry problem solving tasks. We also aim to develop educational interfaces that avoid exacerbating pre-existing performance differences between low- and high-performing students, since low performers do not always benefit equally from the introduction of new computational tools due to weaker meta-cognitive skills (Oviatt, Arthur, & Cohen, 2006).

Cognitive Load Theory

Cognitive Load Theory (CLT) provides a potentially coherent and powerful basis for predicting students' performance when using new educational interfaces, and for designing educational interfaces that effectively minimize cognitive load (Mousavi, Low, & Sweller, 1995; Oviatt, 2006; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; van Merriënboer & Sweller, 2005). Cognitive load involves the mental resources that a person has available for solving problems at a given time. Current work on cognitive load emphasizes limited attention and working memory capacity as specific bottlenecks that continually exert pressure on performance during information processing. Cognitive load theorists have maintained that during the learning process, students can more easily acquire new schemas and automate them if instructional methods minimize demands on their working memory, thereby reducing cognitive load (Baddeley, 1986; Mousavi et al., 1995; Paas et al., 2003; van Merriënboer & Sweller, 2005). To achieve this goal, advocates of this theory assess the "extraneous complexity" associated with instructional methods or interfaces separately from the "intrinsic complexity" associated with a student's main learning task, and then compare performance across different interfaces.

In related educational research, a multimodal presentation format has been shown to support expansion of working memory and better problem solving on geometry tasks than a single visual mode (Mousavi et al., 1995). The advantages of a multimodal presentation format for students' tutorial performance have been replicated for different tasks, dependent measures, and presentation materials, including computer-based multimedia animations (Mayer & Moreno, 1998; Tindall-Ford, Chandler, & Sweller, 1997). When using computer interfaces, it also is known that as cognitive load increases with task difficulty, users spontaneously shift to interacting more multimodally, so a flexible multimodal interface can assist users in self-managing their cognitive load (Oviatt, Coulston, & Lunsford, 2004). Furthermore, researchers have documented that performance by the same person completing the same task improves when using a multimodal interface, compared with a unimodal one (Oviatt, 1997).

In research with elementary school children and adults, active manual gesturing also was demonstrated to reduce cognitive load and improve memory during a task requiring explanation of math solutions. Furthermore, during more difficult tasks, gesturing was especially effective at minimizing cognitive load and improving memory (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). The physical activity of manual or pen-based gesturing is believed to play an important role in organizing and facilitating spatial information processing, thereby reducing cognitive load on tasks involving geometry, maps, etc. (Alibali, Kita, & Young, 2000; Oviatt, 1997; Rauscher, Krauss, & Chen, 1996). For an overview of other user-centered interface design techniques known to minimize cognitive load, see (Oviatt, 2006).

Adaptive Learning and Meta-Cognition

Cognitive Load Theory recently has been applied to the design of educational systems that select problem solving content of the appropriate difficulty level for a given student. In this case, the goal is to deliver an optimal level of difficulty for the student's primary learning task, rather than minimizing extraneous load associated with managing the system interface per se. This interest in student-centered tailoring of problem difficulty was inspired in part by the discovery of the expertise reversal effect, which revealed that the optimal instructional design for novices can be ineffective for more knowledgeable learners because processing redundant information overloads their working memory capacity (Kalyuga, 2006; Kalyuga, Ayres, Chandler, & Sweller, 2003; Salden, Paas, Broers, & van Merriënboer, 2004; Salden, Paas, & van Merriënboer, 2006). Although a novice may require detailed worked examples to establish new schemas, this same information actually hinders the performance of an expert for whom knowledge is already well integrated in long-term memory.

To optimize tailoring of the problem difficulty presented to a learner, some educational studies have assessed both student performance (i.e., problem correctness) and mental effort (i.e., reported subjectively) to gauge the efficiency of learning (Salden et al., 2004; van Merriënboer & Sweller, 2005). Basically, if a student solves a problem correctly and reports low effort, then their next delivered task would be more difficult. On the other hand, poor performance coupled with high effort would result in an easier problem. This research confirmed that adaptive learning protocols result in better learning progress than traditional methods, although basing adaptation on mental efficiency rather than performance alone has not shown demonstrable advantages (Salden et al., 2004). Recent research has attempted to more objectively assess a student's domain expertise as they solve problems, by evaluating the granularity of solution steps, including the number of skipped steps due to having learned and stored a schema in chunked form (Kalyuga, 2006). This pragmatic approach to calibrating a student's level of expertise as they work provides a potential future basis for real-time tailoring of educational systems.

As a related issue to expertise, research has documented that lower-performing students lack the meta-cognitive skills needed to organize and improve their own performance (Aleven & Koedinger, 2000; Winne & Perry, 2000). Among other things, such self-regulatory skills include knowing what type of problem one is working on, its difficulty level, and what type of tools or strategies are needed to solve a problem. Stronger meta-cognitive skills help students identify the best times to use computational tools, and how to use them most effectively. Past work on self-directed help systems has indicated that students frequently do not have the skills needed to utilize such resources effectively (Aleven & Koedinger, 2000). Other recent work has shown that lower-performing students are less aware than high performers of which interface tools will advance their performance best, and in some cases they prefer interface options that are *least supportive* of their performance (Oviatt et al., 2006). Given low performers' lack of savvy regarding computational tools, the introduction of new technology into classrooms risks exacerbating the existing achievement gap between low and high performers, especially if performance differences are not monitored carefully.

Pen-Based Interfaces

Pen-based interfaces have many attractive features for the education sector, including their compatibility with mobility, expressive range, suitability for collaboration, and ability to "bridge" formal, informal, and mobile learning contexts (Cohen & McGee, 2004; Leapfrog, 2006; Pea & Maldonado, 2006). Anoto-based digital stylus and paper interfaces, which span the physical and digital worlds, also are considered a promising interface for knowl-

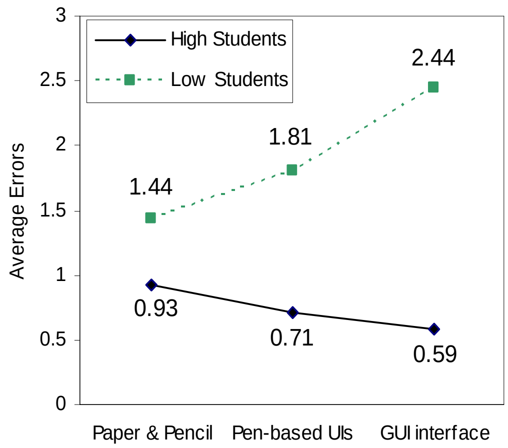

Figure 1. Difference between low- and high-performing students in math errors in the pen (DP, PT) versus graphical (GT) interfaces.

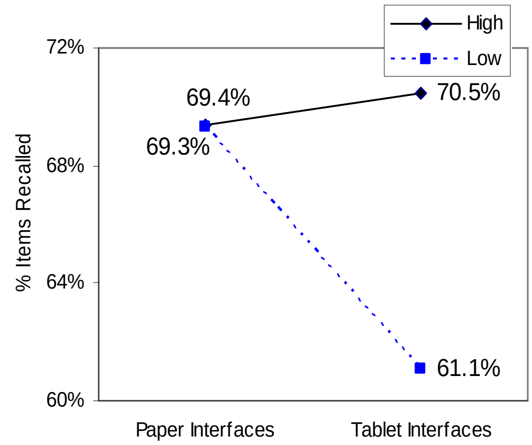

Figure 2. Percentage items recalled correctly by low- and high-performing students using paper (PP, DP) versus tablet (PT, GT) interfaces.

edge-gathering tasks in which users combine, cross-reference, and personalize information from different sources with pen-based annotations (Liao, Guimbretiere, & Hinckley, 2005).

Recent research comparing educational interfaces has shown that interfaces more similar to students' existing work practice also reduce extraneous cognitive load and improve performance during geometry problem solving tasks (Oviatt et al., 2006). A comparison of students' speed, attention, meta-cognitive control, correctness of solutions, and memory revealed that they performed better when using a digital stylus and paper interface (DP) than a pen tablet interface (PT), which in turn supported better performance than a graphical tablet interface (GT) (Oviatt et al., 2006). Cognitive Load Theory provided the basis for making quantitative rank order predictions about student performance with these different interfaces. Basically, the digital stylus and paper interface enhanced performance best because it most closely mimicked existing work practice by incorporating both pen input and the familiar, tangible paper medium. In comparison, the pen tablet interface included the pen but not the paper medium, and the graphical interface least resembled students' existing work practice. Within the math domain, both of the pen–based interfaces support a broad range of expressive input in different representational systems, including linguistic, numeric, symbolic, and diagrammatic. Such pen interfaces are particularly compatible with complex problem solving in domains like mathematics, which requires input fluency in all four representational systems and flexible translation among them to facilitate clarity of thought.

In the previously mentioned study (Oviatt et al., 2006), lower-performing students' ability to correctly solve math problems and remember the problem content they had just worked on were selectively disrupted when using the tablet interfaces, especially with the graphical tablet interface. As shown in Figure 1, high-performing students' errors did not change significantly when using the different interfaces. However, low-performing students' errors increased from 1.44 with pencil and paper (64% correct solutions), to 1.81 with the pen-based interfaces (55% correct), and 2.44 with the graphical tablet interface (just 39% correct). As shown in Figure 2, the study found parallel trends in students' recall of math content. After using paper-based versus tablet-based interfaces, the high-performing students correctly recalled 69.4% and 70.5% of the math content they had just worked on. The low-performing students recalled math content equally well after using paper-based interfaces (69.3%), but their recall dropped to 61.1% on the tablet interfaces, or 12%. From the viewpoint of CLT, the higher extraneous load involved with the tablet interfaces, especially the graphical one, derailed low performers' working memory resources from successfully solving and retaining information about the same problems.

Based on think-aloud protocols, this research also documented that the frequency with which students were distracted by the interface rather than focusing on their math increased a substantial 326% when using the pen tablet interface (e.g., "Oops, lasso didn't work") and 661% with the graphical tablet interface (e.g., "Darn, I mis-clicked"), compared with using paper and pencil. As students became more distracted with the tablet interfaces, their high-

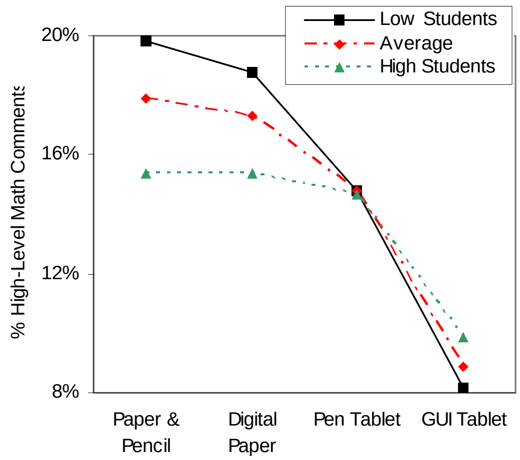

Figure 3. Percentage of high-level math comments for low- and high-performing students using different interfaces.

Table 1. Preference for the paper (PP, DP) versus tablet (PT, GT) interfaces (left), and corresponding math performance levels (right) for low- versus high-performing students.

Students	% Prefer Paper	% Prefer Tablet	% Correct Paper	% Correct Tablet
Low	37.0	63.0	57.5	50.0
High	100.0	0.0	82.5	80.0

level math comments correspondingly declined (e.g., "Oh, it's a 3D problem"), as illustrated in Figure 3. Whereas students' low-level procedural math comments were unaffected, their ability to think at a more abstract and strategic level about the nature of their math problems declined by 50.3% when they used the graphical interface, and more sharply for low-performing students (59%) than for high performers (42%). When asked which interface students would use if they had to perform their best on an AP exam, 100% of high-performing students said they would prefer the paper-based interfaces. However, Table 1 shows that for low-performing students, the reverse was true—63% said they would prefer using the tablet interfaces, even though their performance was more poorly supported by them. This performance-preference paradox reflects weaker self-regulatory skills in the lower-performing students, who clearly were less aware than high-performing students of the tools they needed to perform well (Oviatt et al., 2006).

Goals of the Study

The general goal of this study was to comparatively assess alternative interfaces with respect to their ability to minimize students' cognitive load and support successful geometry problem solving. We were specifically interested in how well different interfaces supported students' expressive fluency while thinking through solutions to problems, and any diagramming they did in advance of beginning a new problem as they clarified their understanding of what the problem meant and planned their approach to solving it. Comparisons were made for both low- and high-performing students while using: (1) existing paper and pencil work practice, (2) a digital stylus and paper interface (i.e., based on Anoto technology (Anoto Technology, 2006)), (3) a pen tablet interface, and (4) a graphical tablet interface that included a keyboard, mouse, stylus, and simplified equation editor. By collecting within-subject data on the *same students' ability to solve the same math problems,* this study aimed to provide a sensitive assessment of the relative cognitive load associated with using these alternative interfaces. Task difficulty levels varying from low to very high also were included to assess how well different interfaces supported performance across a realistic range of tasks. Both low- and high-performing students were studied so new interfaces can be designed that are accessible and supportive of learning for all students. We also were interested in examining the impact of introducing different interfaces on the performance gap between low- and high-performing students.

It was hypothesized that as interface prototypes departed more from familiar work practice, students would experience greater extrinsic cognitive load such that fewer mental reserves would be available for communicating fluently and engaging in advance planning. It also was hypothesized that higher-performing math students would experience less cognitive load than their lower-performing peers, so they would have relatively more resources available for communication and planning. In comparison with using paper and pencil, it was anticipated that introducing new interfaces also would risk magnifying the existing performance gap between high- and low-performing students, because low performers have weaker meta-cognitive skills and are less adept at using new tools.

Methods
Participants
Sixteen high school students who had recently completed a geometry class were included in the study as paid volunteers. All students used paper and pencil materials in their high school math classes, expressed an interest in technology, and were experienced users of graphical user interfaces with keyboard and mouse input. According to teacher records on students' classroom grades in geometry and also students' percentage of correct math problem solutions in this study, half of the students were classified as high-performing and half low-to-moderate. Twelve were female and four male. All students were native English speakers, although ethnic backgrounds varied.

Math Problems and Difficulty Levels
After consulting high school teachers and textbooks, math problems that students had just learned in their geometry classes were selected for the study. Teacher records of average student test performance on specific problems were used as an initial basis for classifying problems, and pilot testing then confirmed these classifications. All math problems were word problems that required translation from linguistic information into symbolic and digit-based information to solve them. Since the majority were spatially-oriented geometry problems, diagrams also were helpful in solving them. In short, successful completion of the math problems required complex problem solving using all four representational systems (linguistic, symbolic, numeric, and diagrammatic), as well as translating among them. These characteristics enabled testing the ability of different interfaces to support flexibly expressive communication patterns, which are required for extended problem solving in domains like geometry. The number, format, and type of information varied in problems of different difficulty levels, such that harder problems involved more steps to solution, information presented in different formats (e.g., integers versus ratios), incidental information not required for solution, and so forth. For further detail on problem sets, see (Oviatt et al., 2006).

Procedure
Students were tested in pairs and given instructions and practice together. They were told that their input regarding the different interfaces would be used to design a math camp for younger children. The student volunteers were shown the four different sets of materials that they would use to solve problems, including: (1) standard pencil and paper, (2) digital stylus and paper (i.e., Nokia stylus with Anoto-based paper technology), (3) tablet computer with stylus input, and (4) tablet computer with keyboard, mouse, and stylus input, which was enhanced with a simplified MathType equation editor containing 11 symbols not on the keyboard (e.g., square roots, powers).

For all four conditions, each problem set was presented on a Toshiba Portege laptop screen, as shown in Figure 4, which included the main word problem (top) along with any terms or equations required to complete the problem (bottom left). In the two paper-based conditions, students simply read the problem on the computer screen but did their work on paper. In the two tablet-based conditions, they entered their work on the computer using Windows Journal for the pen tablet condition, and either MathType or Windows Journal (i.e. using a stylus) for the mixed graphical tablet interface. Figure 4 shows the graphical tablet interface condition, with MathType (left side) and Windows Journal (right side) both open. In the pen tablet condition, Windows Journal was the only input area open, and in the two paper conditions the middle of the screen shown in Figure 4 was blank. In all conditions, students were told they could use their calculator and were free to use their materials any way they liked. With the graphical tablet interface, they could use the keyboard and equation editor or pen input however they wished.

For each of the three computer interfaces, students were given instructions on how it worked and allowed to practice until they were familiar and had no more questions. Beyond orientation, students were told to work at their own pace and concentrate on solving each problem. If they couldn't complete a problem, they were instructed to go to the next. Each student completed 16 math problems during the main test session, four problems apiece in each of the four conditions.

Research Design
This study involved a mixed factorial experimental design, with within-subject independent factors including: (1) Type of Interface: paper and pencil hardcopy materials (PP), digital stylus and paper interface (DP), pen tablet interface (PT), and graphical tablet interface (GT), and (2) Math Problem Difficulty Level: low, moderate, high, and very high. Each student completed a set of four problems per condition, which increased progressively in difficulty. The specific content of different problem sets and order of presentation of the interface conditions were counterbalanced. The main between-subject factor was: (3) Student Performance Level: high, low.

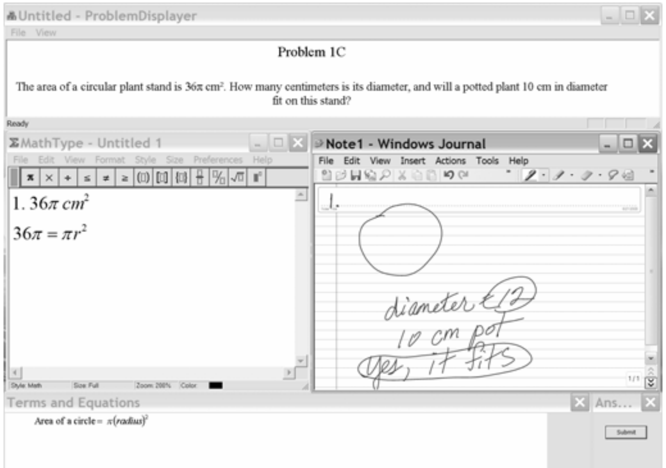

Figure 4. Interface used to display math problems

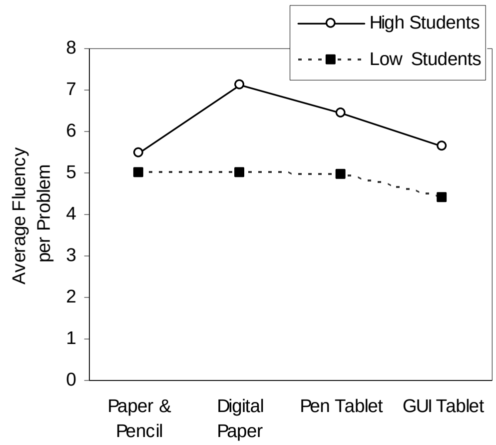

Figure 5. Fluency for high- versus low-performing students in different interfaces

Dependent Measures and Coding

Fluency in Different Representational Systems

The number of (1) words (including abbreviations), (2) digits, (3) symbols (e.g., π), and (4) diagrams that students generated while working on each problem was totaled and then summarized as an average number per problem in each condition.

Advance Planning Prior to Problem Solving

In the domain of geometry, diagramming of the spatial relations among objects is a common initial step that helps students to clarify their understanding of the problem and prepare to work. The number of diagrams that each student produced was totaled and summarized as an average number per problem.

Reliability

Fluency counts were scored again by two independent coders for 13% of the data. These counts matched exactly 93%, 97%, 94%, and 100% of the time for linguistic, numeric, symbolic, and diagram counts, respectively.

Results

Data were available on 256 problem solutions for the dependent measures reported below.

Fluency Using Different Interfaces

For high-performing students, their expressive fluency while solving math problems using different interfaces increased from an average of 5.47 per problem using pencil and paper, to 7.13 in the digital stylus interface and 6.43 with the pen tablet, but dropping back to 5.65 when using the graphical tablet interface. For low-performing students, fluency remained more stable at 5.02, 5.02, 4.95, and 4.42, respectively, for the same interfaces. Figure 5 illustrates that the high-performing students were significantly more fluent when using the two pen-based interfaces (mean = 6.78) than with the other interfaces (mean = 5.56), paired t test, $t = 2.06$ ($df = 7$), $p < .04$, one-tailed, or 22% more fluent. The main source of increased fluency when they used the pen-based interfaces involved producing 2.3 more symbols and 1.5 more digits per problem. In contrast, fluency of the low-performing students did not change when they used the pen-based interfaces compared with the others, paired $t < 1$. Fluency levels also did not differ significantly between paper and pencil and the graphical tablet interface, paired t test, $t < 1$.

The high-performing students' average fluency was 6.17 per problem, compared with 4.85 for the low-performing students, a marginal difference between groups across all interfaces, independent t test, $t = 1.75$ ($df = 14$), $p < .051$, one-tailed. The high-performing students were significantly more fluent than the low performers when using the digital paper and stylus interface, independent $t = 1.99$ ($df = 14$), $p < .035$, one-tailed, and also when using the pen tablet interface, independent $t = 1.93$ ($df = 14$), $p < .04$, one-tailed. In fact, the high performers averaged 36% more expressive fluency when using the pen-based interfaces, compared with the low-performing students. In comparison, these groups did not differ significantly in fluency when using pencil and paper, independent $t < 1$, the

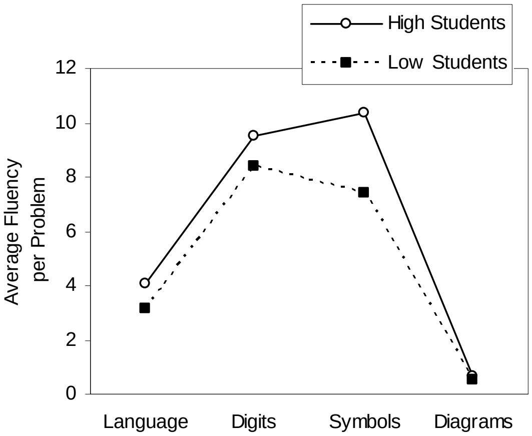

Figure 6. Average fluency for high- versus low-performing students using different types of representational system.

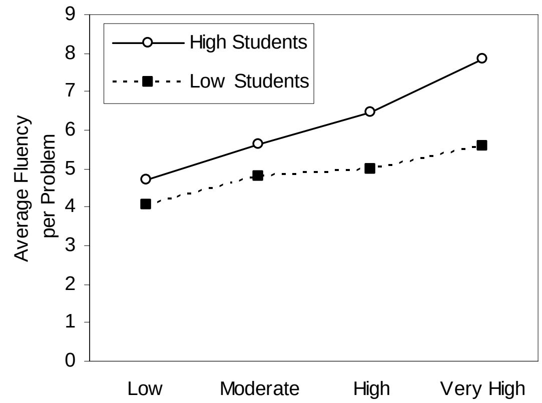

Figure 7. Average fluency for high- versus low-performing students due to task difficulty.

graphical interface, independent t = 1.12, N.S., or even pen input within the graphical interface, independent t < 1. When using the graphical tablet interface in which students had free choice to type or use pen input, 50% of students mixed text and pen input (e.g., using text for digits and formulas, pen for diagramming and labeling), 37.5% provided only pen input, and 12.5% only used text. Overall, 37% of all input was text and 63% pen input.

Fluency in Different Representational Systems and Task Difficulty Levels

As shown in Figure 6, students actively used all four representational systems while solving geometry problems. High performers averaged 4.08 linguistic, 9.54 numeric, 10.38 symbolic, and .67 diagrammatic content per problem, while low performers averaged 3.16 linguistic, 8.37 numeric, 7.38 symbolic, and .51 diagrammatic content. The high performers were significantly more fluent than low performers when using the challenging symbolic content (means 10.38 and 7.38, respectively), independent t = 2.02 (df = 14), p < .035, one-tailed, a 41% increase. However, the groups did not differ in other fluency rates.

As problems became more difficult, high-performing students' fluency increased steadily from 4.73 on low difficulty problems, to 5.63 on moderate, 6.46 on high, and 7.86 on very high difficulty ones. Likewise, for low-performing students, fluency increased from 4.05 on low, 4.78 on moderate, 4.97 on high, and 5.60 on very high difficulty problems. These shifts in fluency represented a significant increase between low and moderately difficult problems, paired t = 3.35 (df = 15), p < .002, one-tailed, moderate and high difficulty problems, paired t = 2.31 (df = 15), p < .02, one-tailed, and high and very high difficulty, paired t = 2.09 (df = 15), p < .03, one-tailed. Compared with low and moderate difficulty problems, on the high and very high difficulty ones students' diagramming increased by 126%, digits by 55% and symbols 27%, whereas linguistic content actually declined 5%.

As illustrated in Figure 7, the high- versus low-performing students also diverged more in their fluency as problem difficulty increased, which became most apparent on the high and very high difficulty problems. While the groups did not differ in fluency at the low and moderate difficulty levels (t < 1 and t = 1.34 N.S.), the high-performing students were marginally more fluent than low performers at the high difficulty level (independent t = 1.65 (df = 14), p < .065, one-tailed), and they were significantly more fluent than low performers at the very high difficulty level (t = 1.95 (df =14), p < .04, one-tailed). As problem difficulty increased from low to very high, the high-performing students increased their fluency by 66%, while low performers only increased by 38%. On the very high difficulty problems, high-performing students were 40% more fluent, on average, than the lower performers.

Planning Prior to Problem Solution

Ninety-four percent of students engaged in diagramming before or during their math problem solutions. Low- and high-performing students exhibited no significant difference in frequency of diagramming, independent t = 1.04 (df = 14), N.S., but considerable individual differences were evident among students. As shown in Figure 8,

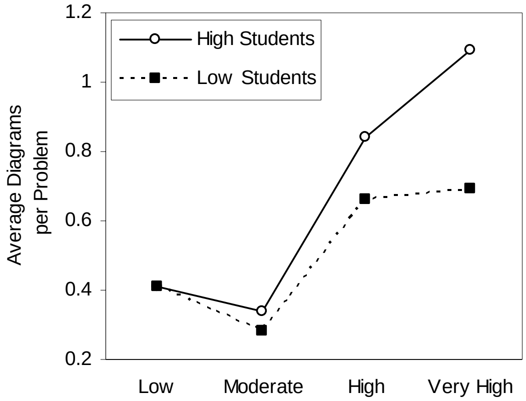

Figure 8. Average number of diagrams per problem as a function of task difficulty.

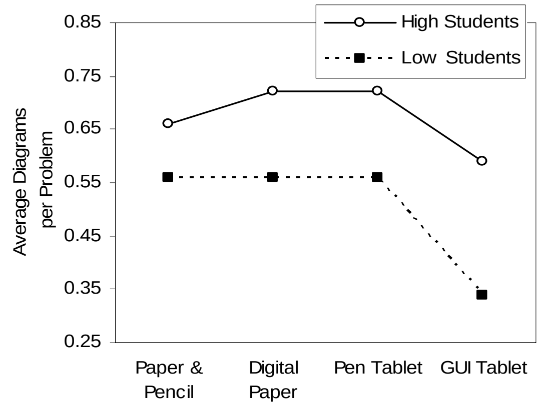

Figure 9. Average number of diagrams per problem as a function of interface.

the average number of diagrams increased with task difficulty for both low performers (means = .41, .28, .66, and .69 for low to very high) and high performers (means = .41, .34, .84, 1.09). A paired t test confirmed that diagramming increased significantly between low/moderate and high/very high difficulty problems, $t = 6.30$ (df =15), $p < .001$, one-tailed. Separate analyses also indicated that both high- and low-performing students significantly increased their diagramming on the high/very high difficulty problems, $t = 5.06$ (df = 7), $p < .0005$, one-tailed, and $t = 4.08$ (df = 7), $p < .0025$, one-tailed, respectively. It is noteworthy that high performers increased their diagramming 158% on the harder math problems, whereas low performers only increased 95%. In addition, a linear regression between task difficulty and the likelihood of diagramming revealed a correlation of .90, with 82% of the variance in students' likelihood of diagramming accounted for by knowing the difficulty level of their math problem.

With respect to diagramming in different interfaces, Figure 9 illustrates that high-performing students averaged .66 diagrams per problem when using pencil and paper, .72 with digital stylus and paper, and .72 with the pen tablet, but dropped to .59 with the graphical tablet—none of which were significant differences, ts< 1. Low performers remained stable at .56 diagrams in all interfaces except the graphical one, for which they dropped significantly to .34, Wilcoxon Signed Ranks test, $z = 1.75$, $p < .04$ (one-tailed), a 39% drop.

Discussion

As shown in Figure 6, students actively used all four representational systems while solving geometry problems. This highlights the importance of developing more powerfully expressive pen interfaces for supporting educational domains like math, which require symbolic and diagrammatic input as well as linguistic and numeric. In addition, 94% of students drew diagrams before solving their problems, and they increased diagramming 117% between low and very high difficulty problems. The pen interfaces both supported diagramming at levels as high as existing pencil and paper work practice, although diagramming dropped 22% when students used the graphical tablet interface—in fact, more sharply by 39% for the low-performing students. Although students in this study were all expert graphical interface users, and the mixed graphical tablet interface also supported pen input, they still used this interface less fluently and with less foresight than the two pen interfaces. This finding is consistent with previous research revealing weaker meta-cognitive skills in low performers (Winne & Perry, 2000), and also less high-level planning among low performers when using a graphical tablet interface (Oviatt, 2006).

As predicted by Cognitive Load Theory, high performers experienced less cognitive load than lower performers when working on the same math problems. As such, they had more mental resources available for increasing their fluency level appropriately as interfaces and problems increased in difficulty. Compared with low-performing students, they were 40% more fluent on the very high difficulty problems, and 41% more fluent with symbolic content. In addition, the higher performers actually were *super-fluent* when using the two pen interfaces—the digital paper and pen interface, and pen tablet interface. They became 36% more fluent with these pen interface tools, although the low performers were not similarly stimulated. This difference between groups in their use of the pen interfaces is important because the activity of self-expression itself can serve to clarify thought.

One objective of geometry teachers is to encourage students to diagram more frequently to facilitate their problem solutions. Like expressive fluency, diagramming can function as a self-organizing activity that assists students in planning clearer problem solutions. Typical student comments about diagramming included: "I'm a visual learner. I like to draw pictures to help me think clearly." And "I need visualizations to figure out the problems." While diagramming is particularly well supported by the more expressively powerful pen interfaces, higher-performing students were more likely to take full advantage of this capability. The high performers specifically responded to harder math problems by diagramming 158% more than on easier problems, compared with just a 95% increase for low performers. This indicates that low performers may need instruction to encourage higher levels of diagramming as an aid to solving difficult problems, and to ensure that they make full use of the pen interfaces.

Table 2.

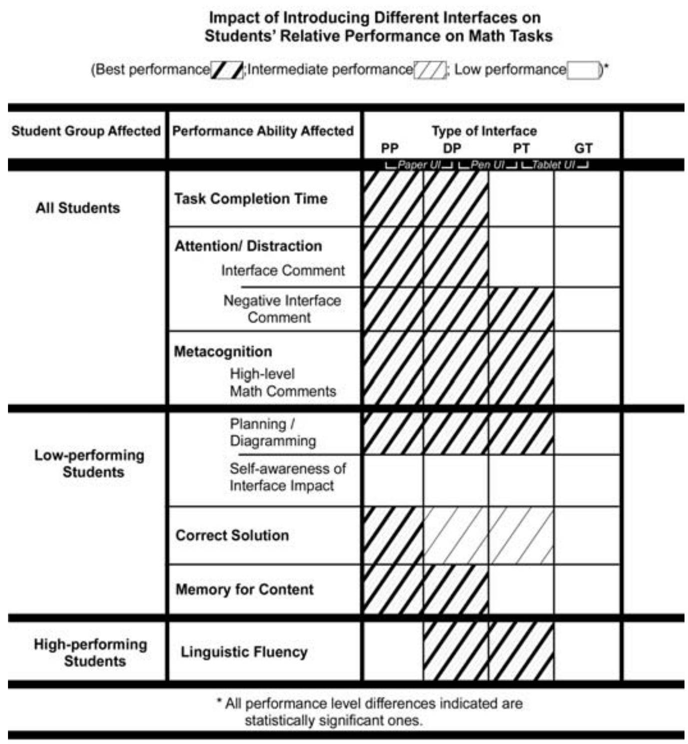

Table 2 summarizes the convergent pattern of results that has emerged based on the present and previous studies that examined the impact of different interfaces on students' geometry performance (see (Oviatt et al., 2006) for discussion of previous findings). Analyses from both studies consistently reveal that meta-cognitive behavior (i.e., diagramming, high-level math comments) decline when using the graphical tablet interface, with advance diagramming specifically reduced in the low-performing students. The present study also showed that high-performing students were super-fluent when using pen interface tools, although low-performing students did not realize the same advantage of these interfaces. As shown in Table 2, the convergent results that emerge from the present and previous studies indicate that the paper and pen interface (DP) supported performance the best of all interfaces compared, with no overall disadvantages compared with paper and pencil work practice. As such, it provides the most viable interface option for introducing digital tools into complex math problem solving activities. The pen tablet interface (PT) was the next most effective, and the graphical tablet interface (GT) least effective. These interface differences are reflected in decreasing advantages from the left to right side of Table 2.

During educational activities, students work on learning to master tasks that stretch existing capabilities and create a relatively high baseline level of cognitive load. For this reason, educational tasks present an ideal forcing function for developing interfaces that minimize load. In the field of math education, it will be especially important for educators to participate in developing new interfaces, especially for weaker students, to ensure that new technologies are developed that do not exacerbate pre-existing performance differences between groups.

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Acknowledgments

Thanks to Rachel Coulston, Marisa Flecha-Garcia, and Rebecca Lunsford for recruiting and scheduling students, and composing and pilot testing math problems. This research was supported by DARPA Contract No. NBCHD030010. Any opinions, findings, or conclusions are those of the authors, and do not necessarily reflect the views of DARPA or the Department of the Interior.

Epistemological perturbations: Using material artifacts to cultivate a knowledge building culture in classrooms

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Abstract: The realization of the pedagogic affordances of many CSCL tools require a social infrastructure quite different from that found in traditional classrooms using "instructionist" teaching and learning practices. We are interested in ways to support teachers and students in making the necessary shift in cultural beliefs and classroom practices in order to integrate such CSCL tools --- a change trajectory that we term the "implementation path" (Bielaczyc & Collins, 2006). In the present paper we discuss a research project focused on integrating Knowledge Forum (Scardamalia, 2004) into the science curriculum of nine Primary 3 and 4 classrooms in a Singaporean school. We investigate the use of material artifacts and offline practices in providing a transition mechanism from traditional classrooms toward creating a knowledge building culture. We are particularly interested in how such artifacts and practices lead to "epistemological perturbations" in teacher's conceptions of teaching and learning.

Schools in Transition

The education system in Singapore is entering a period of change. These changes have their genesis in education policies that seek to develop a nation and its schools for a 21st century economy (www.moe.gov.sg). The goal is to foster in students the skills to learn and adapt in a rapidly changing world. But this requires a radical change in teaching practice, in order to deemphasize the value that knowledge is needed for examination while emphasizing the value of knowledge for solving problems

We believe that learning in a Knowledge Building community supported by Knowledge Forum will support the desired changes in education. Knowledge Forum was first introduced in Singapore in 2001 (Ibrahim & Tan, 2004; Tan, Hung, & So, 2005). Since then, there have been numerous pockets of pedagogic innovation exploring the integration of Knowledge Forum into Singaporean classrooms. However, a scalable model of Knowledge Building communities in classrooms has yet to be developed. Creating such a model is one of the goals of the newly-established Learning Sciences Laboratory in Singapore.

In the present paper we discuss a research project designed to foster learning in a Knowledge Building community as part of the science curriculum of nine Primary 3 and 4 classrooms in a Singaporean school. Unlike other efforts to create knowledge building classrooms with Knowledge Forum (e.g., Bielaczyc, 2001; Caswell & Bielaczyc, 2002; Hewitt, 2002; Ow, Low & Tan, 2004; Reeve & Lamon, 1998), the project did not involve using Knowledge Forum in the first half of the school year. Instead, transition mechanisms were developed in order to scaffold both teachers' and students' entry into the CSCL environment through first engaging in an offline collaborative learning environment. The offline learning environment involved material artifacts that were meant to provide tangible "tools-to-think-with" in transitioning to a knowledge building pedagogy that challenged the more traditional Singaporean pedagogy. Hence, we were designing a new implementation path (Bielaczyc & Collins, 2006) for introducing teachers and students to a sophisticated CSCL tool.

The project has just completed its first year of implementation. This paper provides an opportunity to share our work with transition mechanisms, specifically our use of material artifacts and the "epistemic perturbations" in teachers' conceptions of teaching and learning generated by their introduction. Here we focus on one particular transition mechanism, a material artifact called the "Think Card."

Supporting Changes in Cultural Beliefs and Classroom Practices

Our project is entitled "Ideas First." As the name suggests, our approach places work on ideas by the individual and community as its foremost design consideration. The transition mechanisms that we designed for Ideas First are meant to help transition teachers and students from working with "ideas in physical forms" to working with ideas in the software of Knowledge Forum. Knowledge Forum is a technology-based tool developed by Marlene Scardamalia and Carl Bereiter (1991; 1994; Scardamalia, 2004). Knowledge Forum allows learners to construct a communal multimedia knowledge base. The objective is to engage students in progressive knowledge building, where they continually develop their understanding through problem identification, research, and community discourse. The vision of Knowledge Forum is for students to build collective knowledge with "fidelity to the ways work with ideas is carried out in the real world" (Scardamalia, 2002, p. 6). This vision represents a shift from traditional views of education to "idea-centered education" where problems are found in authentic attempts to understand the world and ideas are viewed as objects of inquiry that can be combined with other knowledge objects, and improved upon (Scardamalia, 2002; Scardamalia, Bereiter & Lamon, 1994).

The Ideas First approach is characterized by four interdependent phases to support students in working with ideas: *idea generation, idea connection, experimentation*, and *pull-together*. Embedded in the phases are Knowledge Building principles that guide the community's work with ideas (Scardamalia, 2002). The Think Card was designed as a way to physically reify the ideas and theories generated by children while they work on problems of understanding.

A "Think card" is a 5x7 card that is divided into two halves. The top half of the card is yellow and has the scaffold "My idea is…" The bottom half of the card is green and uses the scaffold "Something I wonder about …" These scaffolds are intended to help students generate ideas and questions of wonderment which are then shared using the physical classroom walls to create a shared, public space. Students post up their Think Cards on this community space, enabling all children to access the ideas of the class community.

The parallels between notes and views in the Knowledge Forum environment and the "Think cards" and the physical communal space of the Ideas First classroom were intentional design features. Notes in Knowledge Forum and Think Cards are both conceptual artifacts (Bereiter, 2002). These artifacts support learners developing objectified theories and ideas residing in World 3 (Popper, 1972). The objectification of ideas affords learners the opportunity to carry out knowledge work such as generating, comparing, testing, and synthesising ideas. Without the objectification of ideas, these ideas would reside in the mind of individuals impervious to the attention of others in the community. Views in Knowledge Forum and the physical communal space of the classroom walls provide a place in the community for making ideas public. The physical communal space affords the community with opportunities to make connections, improve ideas and even "rise-above" existing ideas.

Teachers saw Think Cards as a means of accessing student ideas in ways that had not occurred in their classes in the past. Through interviews and interactions over the course of the year, teachers described how the Think Cards were a "…. more 'concrete' way to present ideas and to communicate." According to the teachers, the Think Cards allowed children "…. to 'voice' out their ideas" which enabled the teachers to "…. see their knowledge as a whole immediately." Further, teachers noted that, in contrast to the ways they had been teaching science in the past, children were now able to "…. see what their friends *were* writing or thinking about."

Although teachers described the positive value of using the Think Cards, as researchers we also saw that the Think Cards posed a real challenge to the ways teachers viewed teaching and learning. We refer to these disturbances in beliefs about knowledge and learning as "epistemological perturbations." The teachers in the Ideas First classrooms were used to teaching according to an "instructionist," or transmission model, in which children are presented with the sanctioned knowledge they are meant to acquire. The ideas that teachers present to students in such classrooms are viewed as the "right" ideas. However, using the Think Cards made visible the diversity among children's ideas. This idea diversity posed fundamental challenges to teachers' ontology of "right" and "wrong" knowledge. First, posting the Think Cards on the classroom walls served to recognize a diverse set of students' ideas as contributions to the community. Thus, the teachers were faced with "wrong ideas" being made available in the public arena. Second, beyond ideas that were "wrong," the diversity of ideas surfaced many types of "right" ideas beyond the teacher's sanctioned perspective due to the multiple perspectives and emerging understandings expressed. The existence of emerging understandings or ideas in transition indicates the improvable nature of ideas, in contrast to the notion of ideas as either right or wrong.

Technology-based tools often require a shift in the epistemology and practices of education compared to what students and teachers are used to, making it critical that the implementation paths of technology-based tools be understood and supported more fully (Bielaczyc & Collins, 2006). We feel that the construct of epistemic perturbations can help deepen our understanding of the types of issues that need to be considered in supporting teachers along such implementation paths. A deeper understanding of the trajectory of implementation also serves to legitimate the struggles that teachers may face. For example, when faced with such disequilibrium, teachers will often move off the change trajectory and revert to traditional teaching practices. In fact, one of the teachers in the Ideas First classrooms spoke of how she handled the wide range of student ideas by working "to reel them back and get them back into the main content." We believe that analyzing the types of epistemological perturbations that surface can be the starting point for the design of more robust support structures for teachers in transition.

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Acknowledgments

We would like to thank the Ideas First Team --- both the researchers and teachers who made this work possible.

Online but off-topic: Establishing common ground in small learning groups

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Abstract:

There is not yet a great deal of research in formal online learning environments focusing on the "off task" conversations that small groups engage in. This study explores how participants establish common ground in distance learning environments. The e-mail, discussion forum, and chat transcripts of ten small online groups were investigated using computer-mediated discourse analysis. Participants established common ground by focusing mostly on logistics, followed by social and then technical moves. The types of functional moves exchanged revealed that groups were actively engaged with each other to establish common ground, balancing individual focus with a group focus.

Introduction

Computer-mediated communication (CMC) tools are frequently used in educational environments to support collaboration between learners. In fully distance courses they are the primary, if not sole, means by which students talk and work together. While collaboration is desirable for many reasons in educational contexts, research in the area of online discussions has tended to focus on how deep and substantial the conversations are from the standpoint of the instructor or researcher, with an emphasis on cognitive over other types of engagement (Gilbert & Dabbagh, 2005; Wallace, 2003; Zhu, 2006). A sense of disappointment permeates the literature in this area, questioning whether online discussions are really relevant to meaningful learning. In any collaborative effort, however, trust and shared understandings must be in place. Part of establishing trust includes creating group norms and effective ways of being. Establishing common ground is one framework for understanding this process. Grounding requires effort, and less attention has been paid to how groups collaborate on this part of their online experience (Baker, Hansen, Joiner & Traum, 1999).

There is not yet a great deal of research in formal online learning environments focusing on the seemingly "off task" conversations that small groups engage in as they complete learning tasks together. Most studies have focused on the "on-task" elements of the conversation from a cognitive engagement, deep learning perspective (Zhu, 2006). Cognitive presence frameworks have analyzed the quality of the conversations, but the social presence elements have been explored less thoroughly. Knowing that common ground must first be established for groups to effectively collaborate, how groups do this when separated by time and space is of great interest. This study addresses the following questions:

1. What are participants talking about when not discussing the concepts to be learned?
2. How are participants establishing common ground when completing tasks at a distance?

Method

The study took place during a twelve-week graduate level education course at a large midwestern American university. The course was taught entirely at a distance. During two week units students were assigned to small groups to complete learning tasks which were designed according to recommendations by Hathorn and Ingram (2002a). Groups could use e-mail, asynchronous discussion forums or synchronous chat. All tasks required the group to create and submit a final document to the instructor. Each student also wrote a reflection about the learning experience. Sixteen of the twenty-one students enrolled in the course consented to participate in the study; thus a total of ten groups were analyzed.Chat and forum transcripts were automatically archived by the course management system and downloaded into word processing and spreadsheet files for analysis after the course had ended. All e-mail correspondence was sent to the researchers at the end of the course. Individual reflection papers were also downloaded at the end of the course for analysis. A computer-mediated discourse analysis approach was taken to investigate the research question (Herring, 2004; Paulus, 2004). First, messages were unitized into *functional moves*, similar to speech acts or what Henri and Rigault (1996) define as a speech segment: "the smallest unit of delivery, linked to a single theme, directed at the same interlocutor, identified by a single type, having a single function" (p. 62). Functional moves were then coded as conceptual (related to the course objectives), logistics (related to completion of the task), technical (related to the communication tools being used), or social (e.g. small talk) issues. The moves which were not conceptual were analyzed further for the purposes of this study as "off-task" components of establishing common ground. Two researchers, neither of whom were instructors for the course, coded the functional moves. Transcripts from one group (representing 20% of the entire data set) was used to establish inter-rater reliability, with the goal of reaching 80% agreement (Bauer, 2000). Inter-rater reliability of 83% was reached.

Findings

A total of 1,563 non-conceptual functional moves were exchanged by the ten groups. Logistic (1,003 moves) accounted for 64% of the total non-conceptual moves. Social moves (441 moves) were 28% and technology-related moves (119 moves) were 8%. The subcategories of the three main types of moves (technical, social and logistics) reveal that groups were actively engaged with each other to establish common ground through eliciting and providing responses and feedback to each other. They also balanced an individual focus with a group focus. These subcategories are described next.

Technical moves concerned the functionality and use of the communication tools, such as reporting slow server connections or use of the "track changes" feature of Microsoft Word. The groups reached common ground in terms of the technology with the following functional moves: managing use of the tools (61%), supporting each other's attempts to use the technology (23%) and expressing emotions (17%).

The most common functional moves related to technology use were those managing the use of the tools (61%). For example, Trish and Trevor discussed the chat feature of Courseline:

Trish: This is my first chat session using Courseline.
Trevor: This is my second chat in courseline. Although I generally don't like it as well as [the previously used tool], this isn't as bad?
Trish: Not as bad...but there are somethings [sic] missing on courseline that [the previously used tool] has...

Michael in Group Orange asked his group: "Should we create a posting for each question, then we could each post or reply within the question's sub-file?" This reveals a concern with effective use of how best to use the communication tools, and use of questioning to bring all members into the conversation.

There were three broad categories of social functional moves: demonstrating politeness (49%), group cohesion (38%) and socialize/play (13%). Polite behaviors were the most frequent type of social move, accounting for 49% of all social moves. Closing moves, included at the end of messages, were coded as politeness rather than group cohesion, however, elements of group cohesion were often evident in closing moves, as evidenced by these excerpts from Group Tangerine members as they began their work together:

Arthur: I'm looking forward to this assignment!
Libby: I look forward to working with you all and getting to know you more.
Ron: I look forward to a smooth and enjoyable unit.
Lola: . . . looking forward to start our team project.

Logistic moves were the most common and fell into six broad categories: take action (31%), report/manage the task (19%), initiate (17%), provide response (16%), elicit response (13%) and direct others to act (4%). These categories reveal that the participants were highly engaged in establishing common ground about how to accomplish their goals.

The take action category had 31% of the functional moves in the logistics category. By stating their intended action, group members communicated what their individual contributions to the group task would be. Group members stated their availability for working on the task. For example, as this was a summer course several of the group members had vacations, family visits, holiday plans and other obligations to fulfill. This is illustrated in Gregory's post in Group Grape:

Just wanted to let you know that I'm running a little behind, but I should get the readings done by Saturday. Next week is pretty open for me. I went home to San Antonio for a visit last week, and that cost me some study time. Food was great, though :)
As far as chat times (if we decide we need them), I'm home by 4 PM each day, and off all day Thurs-Sat of next week. I generally go to bed at 10 PM (early riser), but anytime before that is fine.

Groups tended to state rather than offer to act, emphasizing quick, efficient decisions and actions, as seen in these posts by Michael in Group Plum:

7/13/2002 11:10:38 AM
I have the document. I will post when I finish. I am not sure how long it will take.
7/13/2002 2:17:05 PM
This is taking some time. It is 2:27. I will keep it about another hour and then post it. I will let someone else work on it for awhile. I plan on picking it up again later this evening.

The three broad categories of initiate, provide response and elicit response illustrate the process of exchanging ideas and information among the group members. Through initiating moves, group members expressed their opinions, made suggestions or further explained their points of view, particularly about how to approach the task. These functional moves went hand in hand with eliciting and providing feedback from other group members, showing an awareness that they were indeed operating as members of a team rather than taking it on individually. We see this type of exchange during Group Plum's chat.

Tonya: How about this? I'll post my lesson plan. I'll read through everybody's colloquium summaries and try to put them into the right boxes and you guys add the ML/Schema stuff?
Tonya: Sound like a plan?
Trish: sounds like a GREAT plan!
Michael: OKay [sic]

Discussion

Even when the groups were not talking about the course content, they were explicitly collaborating together to establish a common ground for the task at hand. They negotiated the logistics of completing the task. They engaged in social interaction and focused somewhat, but not much, on dealing with the technology. While Kirschner et al. (2004) identify that different CMC modes have different technological, social and educational affordances, the groups in this study did not differ much in how they used the various tools to perform communicative tasks. In all of the discourse, participants were interactively negotiating with each other to establish immediacy and iteratively moving between a focus on the individual and a focus on the group.

Early studies examining how groups work together identified similar functional moves as those in this study, but they were not yet theoretically grounded. For example, Curtis and Lawson (2001) noted that groups spent time planning, contributing, seeking input, monitoring and using social strategies. Stacey(1999) found that groups spent time clarifying ideas; obtaining feedback; sharing perspectives, resources and advice; seeking group solutions; negotiating meaning; practicing new language; providing emotional and technical support; conveying commitment to the group; changing roles as needed and managing group activities. All of these moves are consistent with those found in this study. Establishing common ground could perhaps integrate these and other frameworks used to understand online discussions, such as the idea of presence (Lombard & Ditton, 1997; Garrison et al. 2000; Russo & Campbell, 2004), sense of community (Brown, 2001; Haythornthwaite et al. 2000; Hill et al. 2002; Wegerif, 1998) and group norming (Graham, 2003). There is overlap between the findings of this study, for example, and those of Hill et al. (2002) who identify infrastructure and interaction strategies as two keys to building community online.

The frequency of eliciting and providing responses to each other (nearly 30% of all logistics moves) shows an emphasis on engagement and communication among group members, reflecting the negotiation process often evident in establishing common ground. Taken together the moves exchanged by the groups in this study fit the communicative functions for explicitly establishing common ground: conveying that he/she is willing and able to 1) continue the interaction, 2) perceive the message, 3) understand the message, and 3) react and respond, accept or reject the message (Baker et al, 1999). O'Sullivan et al. (2004) explain that in order to create immediacy at a distance, a language of approachability and regard should be used. The moves used by groups in this study reflect approachability and regard.

Makitalo et al. (2002) found that groups engaged in deeper level discussions used both social and cognitive cues to encourage participation. These included strategies of questioning, negotiation, providing evidence of understanding, a positive willingness to continue the conversation, and supportive feedback. However, agreeing too soon without negotiation kept discussions at a more surface level. This illustrates the importance of examining both the off-task and on-task conversations for a comprehensive understanding of what happens in online learning groups.

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Collaboration, Computation, and Creativity: Media Arts Practices in Urban Youth Culture

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Abstract: The focus of this paper is to turn our attention to the arts as an understudied area within the computer-supported collaborative learning community and examine how studying the learning of arts and programming can open new avenues of research. We analyze urban youths' media arts practices within the context of the design studio, particularly by focusing on how collaboration, computation, and creativity play out within this context. We utilize a mixed methods design that draws upon three approaches: (1) participant observations; (2) media arts object analyses; and (3) comparative in-depth case studies. Aspects of new literacy studies, social theories of literacy, and situated learning guide the methodology and interpretation in this study. Media arts projects like these are not well understood in the research literature but have the potential to teach us about learning and literacy in the age of multimedia.

Introduction

Researchers interested in computer-supported collaborative learning have paid little attention to the field of arts and design education as the more prominent focus has been on science, mathematics and to a lesser degree, social studies and language arts. Among a number of reasons that can explain this absence of interest is the lack of new technologies in the arts education curriculum. Recently, the Arts Education Partnership (AEP) issued a call for research to further investigate 'New Technologies and Arts Learning,' noting that "[n]ew technologies…are changing the nature of arts education" (AEP, 2004). The intersection of arts and technology (called "media arts" here) is a relatively new field that has implications for both the arts and computer sciences, and more generally, the role of digital media. The focus of this paper is to turn our attention to the understudied area of media arts and examine how media arts practices, collaborative support, and creative expression evolve within an inner-city design studio.

A design studio found at a Computer Clubhouse in South Central Los Angeles offers a promising opportunity to explore the ways in which youth culture is already making use of new media as tools for communication and expression, particularly capitalizing on software that allows designers to use computation or computer programming. Youth in the Clubhouse engage in applications that encourage skills beyond typing and general computer familiarity, allowing participants to use various forms of media art as tools for expression. "Media art" is used here to encompass all forms of creative practice involving or referring to art that makes use of electronic equipment, computation, and new communication technologies (Muchnic, 2005; Poissant, 2005). The personal access points, appropriation of digital media for personal and creative expression, and the role of social support in the making of media art projects like these are not well understood in the research literature. However, they offer promising opportunities for how youths' media culture and media arts practices can be used to support expanded views of literacy, learning and expression, which are more open to new technologies, respond to new media, and extend the typical classroom.

The focus of this study is to document, describe, and analyze urban youths' media arts practices within the context of the design studio, particularly by focusing on how collaboration, computation, and creativity play out within this context. We define "media arts practices" as the means by which one engages in media art and the reasons and motivations for doing so. To investigate the aforementioned goals, we are utilizing a mixed-methods design that draws upon three primary approaches: (1) participant observations, (2) media arts project analyses, and (3) comparative in-depth and longitudinal case studies. For the purposes of this paper, we focus on findings from one of our case studies. Our methodology and interpretation in this study are guided by social theories of literacy (Barton & Hamilton, 2000), new literacy studies (Buckingham, 2003; Gee, 2003; Lankshear & Knobel, 2003), and discipline-specific theories of situated learning.

Defining Media Arts Practices

Today, literacy can be broadly defined as including any type of communicative interaction involving speaking, reading, listening, and writing with text in print and non-print forms (Hagood, Stevens, & Reinking, 2002). Those interested in looking at expanded notions of literacy within youth cultures have found it useful to apply a social theory of literacy (Barton & Hamilton, 2000; Moje, 2000). Commonly, this group of scholars posits that literacy is best understood as a set of social practices, which can be inferred from events and mediated by written, visual, and other types of texts (Barton & Hamilton, 2000). Hence, the basic unit of a social theory of literacy is that of literacy practices, defined as the general cultural ways of utilizing language (Barton & Hamilton, 2000). Although practices are not observable units of behavior, since they also involve values, attitudes, feelings, and social relationships, one can observe "literacy events" being mediated by texts (Barton & Hamilton, 2000). By introducing media arts practices, we are trying to broaden our view of literacy practices to describe the ways in which individuals use literacy and learn to be literate within the specific context of new media.

As the title of our paper suggests, we are focusing on three aspects that we feel are particularly important to media arts practices: computation, collaboration, and creativity. Computation draws our attention to the role that technology and computer programming plays in the media arts practices. Programming in this context is less about code and more about creativity or personal expression. While case studies of work in the design studio give us only a partial understanding of the larger design culture, they do provide us with an understanding of how individuals are able to repurpose the design environment for personal expression. Collaboration within this context takes on many forms. The design studio environment emphasizes the social context of media arts practices, which sets the stage for peer to peer and member to mentor types of collaborations.

Case Vignettes: Brandy

Brandy is a nine-year-old, African-American girl that is a regular member of the Computer Clubhouse, attending 2-3 times per week over a four-year period. At school, Brandy self-reports that she was nicknamed "special ed" by her friends and often talks about how she's teased frequently by others in class. She struggles in school, especially in core subject areas such as reading and mathematics. As Brandy enters the fourth grade, she is unable to read more than a handful of words, which include her name and at times, Brandy is unable to recognize simple three letter words like "you". Consequently, we would characterize Brandy as being pre-literate in a traditional sense. At home, Brandy has a supportive, large extended family consisting of many cousins. Although not a representative example of Clubhouse youth, Brandy's case presents an opportunity to take a closer look at literacy and learning.

The first literacy event important to tracking Brandy's development occurred when Brandy chose to open computer-programming software for the first time in October 2004. This took place through her work with a mentor as a more expert computer resource, standing in opposition to Brandy's unwillingness at the time to work with other members. In Brandy's first exposure to computer programming, she was drawn to the cat that appears as the first Sprite at the start of any new project. Brandy created a storyline about this character that evolved into her first project. Drawing on her knowledge of Tom & Jerry cartoons, she added a mouse for the cat to chase and a house for the mouse to safely hide. Notably during this first session, Brandy had very little interest in programming. Instead she was satisfied to move the characters as she was talking, somewhat akin to older forms of media like the Color Forms or moveable stickers that were popular toys in the 1980s.

Nearly a year and a half later, Brandy has become known for computer programming projects, even developing a particular style. In April 2006, Brandy designed a birthday card for the Clubhouse Coordinator along with one of her peers (as well as a mentor). In this project, Brandy took the lead, programming three Sprites including a cookie, milk, and some stars. She programmed the three objects to spin and change color using programming concepts like loops and conditionals. Although she didn't explain why she's doing what she's doing to the others, she did make an attempt to teach them by a visual demonstration. Despite Brandy's ability to do sophisticated work on the computer (and was now in many ways technologically fluent), Brandy was still unable to read at grade level and had very much stayed at the same level in both reading and writing.

Discussion

In our discussion, we come back to the three central themes of the paper: Collaboration, computation, and creativity in media arts practices of urban youth. From the case study, we learned that computer programming or computation could be embedded and used in many ways. Brandy's case illustrates that computation can be used as a way to tell stories or to create personally meaningful artwork in the case of the birthday card. Computation is also a learned skill that becomes useful as youth, even those like Brandy that are unable to read, can use for creative production. Although further study is needed, Brandy seemed to have navigated the programming environment by memorizing a subset of commands to find them visually on the screen. In this case, having more than one semiotic system at play can be useful. Brandy seemed to use shape, color, text, and trial and error to memorize and recall the commands that she needed for her projects. Collaboration seemed to be a critical component in the media arts practices at this design studio. Youth not only learned about computer programming from their social participation but they also became motivated by collaborating with peers and mentors to create and share work. As many other researchers have noted, having an audience for the media artwork is key to production. In this case study, we see that collaboration is an indicator of more advanced membership in the community. Brandy only moves to production and computer programming because of the suggestion made by the mentor. Brandy in turn, as she became a more expert programmer takes the lead to introduce and teach others to program. This highlights the importance of collaborative exploration in informal learning environments as it augments Brandy's role at the Clubhouse and deepens her knowledge of computer programming. Creativity in this context can take on a variety of forms. Most importantly we feel that youth were able to creatively insert themselves and their interests into their media artwork. In the case of Brandy's artwork, her personal style and the inspiration for the work reflected Brandy's interest in cartoons and her personal connection to the Clubhouse mentor. Opportunities such as the ones presented in this paper, are particularly important for urban youth who are often seen as pushing new adaptations and transformations of media but are also perceived as standing on the sidelines of technology development and production.

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Acknowledgments

A dissertation fellowship from the Spencer Foundation to the first author supported the work reported in this paper. This work was also supported by a grant of the National Science Foundation (NSF-0325828) to the second author and conducted in collaboration with Mitchel Resnick's research group at the MIT Media Lab. The views expressed are those of the authors and do not necessarily represent the views of the supporting funding agencies or the University of California, Los Angeles.

Student Competition in Computer-Mediated Conferencing Courses

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Abstract: The current study explores student perspectives on competition in asynchronous computer conferencing courses. A survey was distributed to 57 students enrolled in graduate-level distance education programs. Nine of these students participated in extensive interviews. The findings indicate that students experience subtle forms of competition while participating in their online courses. Most manifestations of competition appear to have few educational benefits. It is posited that marking schemes that focus on individual accomplishments may increase feelings of competition and undermine efforts to foster collaborative practices. To reduce the negative effects of competition, course instructors may need to develop assessment strategies that reward group, rather than individual, accomplishments.

Introduction

Recent studies of computer-mediated conferencing (CMC) courses have begun to uncover some of the complex social and cultural factors that influence online interaction. The purpose of this investigation is to research the role that competition plays in students' online exchanges. The topic of competition, although studied extensively in face-to-face classrooms (especially at the elementary and secondary level) has received relatively little attention in CMC contexts. Yet there is good reason to believe that even in the most well designed courses, competitive pressures for grades can have an effect on how students interact with their peers. The goal of the current study is to examine student experiences of competition, and to explore how these experiences shape learner attitudes and behaviors.

Theoretical Framework

Few studies have investigated the role of competition in asynchronous CMC. This may be due, in part, to an assumption that competition is not an important factor. There is currently no concrete evidence suggesting that students perceive their online courses to be less competitive than face-to-face ones. However, there are reasons to believe that online contexts eliminate at least some of the competitive pressures that students experience in regular classrooms. The pressure to perform is one such example. Regular classroom discussion is constrained by time and by social conventions such as turn taking, which regulates how many people can speak at once (Tannen, 1989). Online environments, on the other hand, are more equalizing in the sense that everyone can participate whenever they wish. There is no competition for the floor (Harasim, 1990; Althaus, 1997) and interruptions are impossible (Althaus, 1997). Even the pressures of impromptu contributions are eliminated (Wegerig, 1998) because CMC allows people time to reflect before committing their ideas to the public space (Mason & Kaye, 1990; Jaffee, 1997). Thus, the very design of CMC environments is thought to reduce competition in favor of more egalitarian participation patterns and collaborative peer engagement (Eastmond, 1992).

Despite the aforementioned advantages of computer conferencing, it is plausible that students still experience a sense of competition in CMC environments. Unlike face-to-face discussions, which have no permanence, the interactions that take place online are preserved for long periods of time. Each student's contribution to the class discussion is highly visible and remains available to the instructor for assessment purposes. Most CMC students are aware that the quality of their online submissions can easily be compared against those of their classmates. This arguably places more pressure on students to perform at a level that meets or exceeds the performance of their peers. Online competition may also be produced by course marking schemes. English and Yazadani (1999) point out that it is fundamentally inconsistent for an instructor to encourage students to collaborate, but to grade students individually--especially if people feel that final marks are based upon relative measures. Such a situation can promote competitive pressures that increase learner anxieties and undermine the instructor's collaborative goals. Consequently, the purpose of this research is to explore the role that competition plays in online courses. Do many students experience a sense of competition? How does it manifest itself? How do students respond to the competitive situations they encounter? By exploring these questions it is hoped that we can develop a deeper understanding of the social processes that promote and interfere with online collaborative learning.

Methods and Data Sources

Fifty-seven distance education students were recruited to take part in the study in the fall of 2004. At the time, all participants were enrolled in graduate-level distance education courses at the University of Toronto. A questionnaire was distributed to identify some of the more widely held online practices shared by the participants. Follow-up interviews with nine of the participants provided the researchers with in-depth perspectives of learners' perceptions of competition in their online courses.

Results

Data analyses revealed that many students perceive their online courses to be competitive environments. Competition was evident in students' participation habits, and manifested in how they submitted discussion notes.

Participating Early

In their interviews, students frequently commented on the importance of participating early in the discussion forum. Early participation, it was felt, enabled them to gain the floor and influence the direction of the discussion. One student, Dave, remarked how staying up late allowed him early access into the online discussions. His strategy was as follows: "At 12:01 after the instructor had posted something I was the first person to respond, and that influenced the discussion. It was an experiment, and it demonstrated to me that this was in fact, the correct way to go." Natalie explained that early participation provided increased chances of posting "correct" responses. She explains: "As soon as an assignment or a question is posted by the instructor, if you're early to answer it, then you're more likely to get it right because there are really only 1 or 2 possible right answers."

Volume of Posts

Competition also seemed to affect the number of discussion messages that students contributed. In their questionnaire responses, 82.5% of participants responded that they felt pressured to contribute a certain number of notes to the conference (see Figure 1). This is not surprising, since many online courses award a grade for participation. When gauging their performance, many students felt it was necessarily to compare their participation levels against those of their classmates. As Katherine explains:

> I leave no stone unturned and that's probably irritating to some people who don't have the time. [Other students] can be very annoyed when they think that somebody's postings have said it all or raised the bar for the week, or left them scrambling to come up with additional brilliant comments for the professor. I have sympathy for that. If I were working 9 to 5 and I came home on Friday nights to do my postings and the folders were absolutely chock-full, what am I going to say?

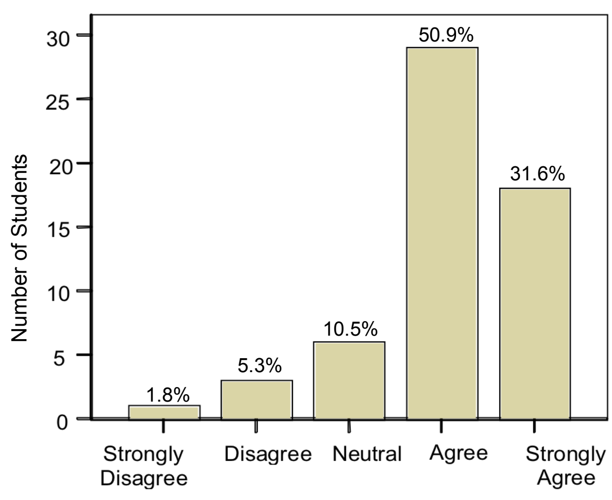

Figure 1. "I feel pressured to regularly contribute a certain number of notes to the class discussions." (N=57)

Quality of Posts

In their interview responses, many participates reported feeling concerned about the quality of their discussion messages. In their survey responses, 86% of participants admitted feeling pressured to make significant intellectual advances that pushed discussions to a deeper level. More often than not, this pressure was associated to the grade awarded for online discussions. Deidre described a practical aspect of her online participation:

> If you're getting marked on things, then you're going to do a bang-up job but if there's no mark, you're just kind of reading through things. That's the reality of university; it's based on marks. You want to do what your professor says so you can get the marks and pass, especially when you're paying $900 for the course.

Competition also affected writing style. To some students, notes were like "mini essays", messages that reflect a student's work and effort in the course. To impress the instructor, many students felt it was necessary to include references to course readings in their notes in order to distinguish themselves. As Jennifer explains, "most people yardstick or measure themselves against other people's postings; they see how the professor may perceive them in relation to other people. You know, the difference online is that it's like you're submitting essays all the time."

Student Attitudes towards Competition

In their interviews, many students described how they felt about competition in their online courses. In many cases, students felt that feelings of competition led students to show off when participating online. In the words of one student, competition "pits individual learners against one another; it raises the risk level." Laurie, a part time student, commented that competition was detrimental to student learning. In her own words:

> I don't see [online courses] as a place where you actually construct new knowledge or perhaps synthesize ideas. It's like someone will post something and people do their best to better or one-up them by inserting some kind of article link or something.

Conclusions and Educational Significance

This paper describes a variety of ways in which students perceive competition to be occurring within their CMC course. The findings support Lipponin's (2002) observation that peer collaborative learning is not always free of conflict and competition. Some forms of competition may be educationally beneficial. For example, a situation in which students compete to produce high-quality, incisive messages may be educationally advantageous for the entire class. However, most manifestations of competition have few educational benefits. Marking schemes that focus on individual accomplishments (e.g., the number of messages posted, the quality of individual messages) may exacerbate feelings of competition and undermine efforts to foster collaborative practices. In order to reduce the negative effects of competition, course instructors may need to develop assessment strategies that reward collaborative, rather than individual, accomplishments.

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Wiki design for teacher interventions in collaborative production

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Abstract: In this poster we report on a process of re-designing a wiki. From previous research we have found that while this type of software is conducive to collective knowledge advancement, it needs to be further developed. Socially we develop a teacher mode where the teacher can trace and directly support learners' activities. Technologically we develop prompts, reminders and guides for subject specific development. We aim to contribute to developing CSCL related classroom practices by developing the XWiki application for such purposes.

Aims

In this poster we describe an ongoing redesign of a wiki. A wiki can be described as a collective, networked resource where in principle, anyone can contribute, revise, and delete and where contributors' changes are immediately accessible on the web. It rests on principles of mutuality and transparency. Contributors do not need to learn complicated mark-up or programming languages. From previous research (Lund, 2006; Lund, forthcoming; Lund & Smørdal, 2006) we have found that while this type of software is conducive to collective knowledge advancement, it needs to be developed in order to afford more support for CSCL practices. Thus, our aim is to re-design a particular wiki (Xwiki) with such supporting features.

We argue that this type of software holds genuine collaborative potential. This potential is partly found in the wiki's architecture; partly in the activities it affords. We present wiki design principles that balance learner exploration with more collaborative and goal directed efforts.

Several studies focusing on learning and ICT show that specific elements in the software are conducive to learning, mainly categories, technological "prompts" or "reminders" (Scardemalia & Bereiter, 1996; Future Learning Environments, 2006). For example, an application can remind the user about vital categories in a school subject. At the same time, we see that teachers struggle to participate in learner activities that are enacted offline as well as online. Often, teachers resort to working offline, leaving the online activities to learners alone.

Wiki activities seem to shift the epistemological position of its users from private ownership of information entities to collectively produced networks of information (Lund, 2006; Lund & Smørdal, 2006). However, not only studies of wiki environments have informed this design. The re-design can also be described as a further development of previous CSCL design efforts where categories, prompts and reminders have been vital. Findings from studies of these environments in schools emphasize that we need to develop more advanced learning resources as part of the institutional development of schools (Wasson and Ludvigsen, 2003). It is the aim of the present design effort to support conceptualization of specific phenomena in a knowledge domain (Ludvigsen & Mørch, 2003). The overall goal is to bring the knowledge domain more to the front in collaborative applications. The purpose of the activities and the connection between different activities have often been left implicit (Rasmussen, 2005). Consequently, the students are left to author much of the task as part of their collaborative work. These findings have informed the current stage of the design process.

Methodology

Our design reflects an ongoing, longitudinal intervention study at a Norwegian Upper Secondary School. It rests on principles of design-based research where interventions are iterative, theory-informed and aim to capture the ecology of the learning situation. Thus, we see the development of wiki design as intimately connected with the activities in which the wiki is appropriated, with the types of tasks it lends itself to, the types of assessment that can be developed and learners' access to social and material resources.

We draw on previous analyses on classroom interactions and discourse and with a particular view to the relationships between verbal and non-verbal, object-oriented activity. Together with log files and questionnaire responses from participants we accumulate a thick description of classroom use of wikis that inform our design work.

We have chosen the XWiki <www.xwiki.org/> to implement new designs. XWiki is chosen due to its rich feature set and its basis of open source middleware and many powerful programming interfaces. The XWiki affords a shared production resource dedicated to a school class jointly developing content over time.

Our design builds on 'Knowledge forum' and the first and second generation of 'Future Learning Environments' where prompts and categories inscribed in the leaning environments provide teachers and students with tools to think and to scaffold their collaborative efforts (Scardemalia & Bereiter 1996; Wasson and Ludvigsen, 2003; Ludvigsen and Mørch, 2003).

Implications for educational design

As for learner and teacher activities in wikis, there are so far few studies. The ones we have conducted show that teachers only to little extent see a place for themselves in a wiki. Thus, we have found that careful analysis and development of technological prompts and meta level features needs to be aligned with a perspective of both teacher and student participation. Design interventions that are only directed toward scaffolding student production seem not to be sufficient (Rasmussen et.al. 2003). Thus, in our design both teachers' and students' production are a direct concern. We suggest the following design features:

We develop the relationship between automated prompts and the teacher/learner participation by means of meta-level functions in the wiki. One example of automated prompts in wikis is the different text mark-up colors to indicate the direction of the work in progress. Colors may denote argument, counter-argument, example, questioning, conclusion etc.

- We develop teacher support for teacher monitoring and participating in student activity in order to initiate and sustain the work also in the online setting. We develop "activity maps" to trace who is working with what, what collaboration patterns emerge, what is the status of the collective object, how are the texts structured etc.

- Teachers may want to directly engage in the student activity by providing questions, comments, directions, critique etc. This requires that the XWiki affords a teacher's space or mode that is flexible and easily accessible.

- Learners have spaces for individual creation of content to show the relationship between individual and collective content production.

The wiki challenges our notions of ownership and individual approaches to knowledge construction and this has implications for theoretical understandings as well as for educational design.

Theoretically we aim to contribute to an understanding of collective knowledge advancement and how this involves new CSCL practices emerging amidst the historical and institutional ones. The epistemological shift from individual to collective production can be seen as an example of sociogenesis; how we come to understanding through social interaction mediated by cultural tools.

As for educational design we see the need to prepare teachers and learners for collective knowledge advancement. To the best of our knowledge, teacher education (at least in Norway) does not address collective approaches in a principled and theory-informed manner. Consequently we see a great need to develop CSCL related classroom practices and didactics that embrace individual as well as collective and networked knowledge construction.

Our perspective can be crystallized in efforts to co-develop technology and learning practices conducive to collective knowledge advancement.

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Scaffolding Preservice Teachers Online: The Roles of Interest and Mathematical Beliefs

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Abstract: Discourse analysis and grounded theory were used to study the responses of 12 preservice teachers (PTs) to scaffolding: 6 received content-informed scaffolding and 6 received performance feedback. PTs receiving content-informed scaffolding varied in the content and form of their scaffolding from PTs receiving performance feedback. Readiness to learn from scaffolding appears to be influenced by interest for mathematics and problem-oriented mathematical beliefs.

Introduction

Preservice teachers (PTs) often have limited knowledge of mathematics and this then impacts their work with mathematics and the way in which they are then prepared to work with their own students (RAND Study Panel, 2002). The Math Forum's *Online Mentoring Guide* (OMG, mathforum.org) was developed to support PTs to learn how to scaffold the mathematical thinking of elementary pupils working with nonroutine challenge problems. Embedded in the task is the need to work with and practice work with mathematical thinking. Studies of the OMG indicate that without mathematical content knowledge, PTs are not in a position to effectively facilitate the development of elementary students' mathematical thinking, nor are they in a position to further develop their own mathematical thinking independently (Renninger, Ray, Luft, & Newton, 2006a). These studies indicated a need for PTs to receive content-informed scaffolding themselves—scaffolding that is based in mathematics and enables the learners to make connections to, develop strategies, self-regulate, and be emotionally supported; findings from this work suggest that PTs can benefit from content-informed scaffolding that helps them to focus on mathematics, and the experience of receiving feedback that is then faded over time (Renninger, Luft, Ray, & Newton, 2006b). Unanswered in this work is the question of how the content and format of content-informed scaffolding differs from the content and format of performance feedback, and how PTs respond to Mentor's suggestions based on these differences. Moreover, consistent with the NRC (2001) suggestion that a key strand in mathematical proficiency is productive disposition, the roles of PT interest and mathematical belief about mathematics were further investigated using discourse analysis (Gee, 1999) and grounded theory (Strauss & Corbin, 1990).

Background on the OMG

The OMG is an asynchronous collaborative tool for supporting PTs to learn how to provide online scaffolding to learners working with nonroutine challenge problems. Lessons in the OMG each include a 4-phase process of doing, reflecting/discussing, interacting with an experienced mentor, and synthesizing the experience of the previous three phases. After completing the lessons in the OMG, PTs in the present study were assigned elementary student submissions (threads) to the Math Forum's Fundamental Problem of the Week (FunPoW) to scaffold. PTs drafted a response to the solution, which was read over by a Mentor who either sends it back to the PT suggesting needed revisions or sends it on to the elementary student.

Methods

Briefly, discourse analytic methods and grounded theory were employed to study the work of 12 PTs, 6 of whom received content-informed scaffolding and 6 of whom received performance feedback, 3 in each group were identified as having more-developed interest and 3 were identified as having less-developed interest for mathematics. All exchanges between the Mentors and the PTs were archived. Analyses of these data addressed: (a) whether PTs were more likely to make effective use of mentor suggestions if they were content-informed, and (b) the role of PT interest and mathematical beliefs on readiness to work with mentor scaffolding. Analyses addressed both content and form (see Fig. 1).

PT Response:

Hello Student 1!

Thank you for submitting your solution to this problem. You did a good job mathematically

applying your strategy and finding the correct solution. Congrats!
There are only a few minor suggestions I could make to improve your solution's clarity.
I really enjoyed how clear your chart was, but there are some units missing. You remembered to label the total "miles" on the walking section of the chart, but there are no similar units for the miles that Zach rode the horse. Also, make sure you leave a space when writing fractions otherwise, 3 and 1/2 looks like 31/2.
Always try to reflect on your work and check it for accuracy. I look forward to reading your revision.
~PT 1

Coded Mentor Feedback:
The biggest suggestion I have is that instead of asking the student to give a reflection, try to encourage them to do so with questions.
Sometimes I ask questions like: Was this problem hard or easy for you? Why? Did you do anything to double-check your answer was correct? Did this answer surprise you? Did you think it would take longer or shorter to walk and ride 50 miles?
(**Content:** ***Model Reflection [Math Pedagogy]*** **Form:** ***Telling, Specific, No Explanation)***

PT's Revision [due to space, only additions are noted]
Also, I liked that you added your mileage from both walking and riding together to see how many miles Zachary had traveled. What made you decide to do this? Could you explain this process to me and how it relates to the total miles Zach had to travel?
Now that you've done such a good job in answering the problem and explaining your solution, could you show me how you checked your answer to make sure it was right? What did you think of this problem? What was the hardest part? What made you decide to use your graph to help you explain?
(PT **UNDERSTOOD** ***Mentor's suggestion to Model Reflection. Evidence: Added own examples of reflective questions)***

Figure 1. Sample, Coded PT and Mentor Exchange

Results

How do the content and format of content-informed scaffolding differ from the content and format of performance feedback, and how do PTs respond to suggestions based on these differences?

PTs who received content-informed scaffolding had different patterns of response to their Mentor's suggestions than those who received performance feedback. Findings indicate that:

a) Mentors using content-informed scaffolding, encouraged PTs to:
   - focus more on mathematics and math-specific pedagogy than mentors giving performance feedback, and mentors giving content-informed scaffolding were more varied in the content of the feedback they gave.
   - vary the types of sentences they use, mixing statements, open-ended, and leading questions.
   - focus on whether and how the elementary student was evidencing mathematical thinking to generate questions that would model reflection and encourage the elementary student to reflect in the process of answering questions.

   Mentors using performance feedback were likely to lead PTs to:
   - tell the elementary students what to do, and did not encourage PTs to ask leading questions.
   - led PTs to use only statements.
   - led PTs to comment on the inadequacies of elementary student work, suggesting that the students were cheating or not doing their work.
   - told elementary student to reflect without providing a model.

b) How did the PTs respond to the different forms of mentoring?
   PTs in both groups were predominantly told what to do and were likely to parrot the suggestions of the Mentor. However, PTs receiving content-informed feedback were also likely to understand what they were told to do and were able to rephrase the Mentor's suggestions as their own words when responding to the elementary students, whereas the PTs who received performance feedback were not. PTs who received

content-informed feedback responded differently to being told what to do and receiving information about what to do in the form of a question. They were less likely to parrot the information provided by the Mentor, but they also were more likely to make mistakes.

What is the impact of PTs' interest and problem-oriented mathematical beliefs on their readiness to work with scaffolded feedback?

PTs' readiness to learn from content-informed scaffolding was mediated by both their interest for mathematics and their problem-oriented mathematical beliefs. Interestingly, however, while some PTs had higher interest for math and were more likely to be problem-oriented in their mathematical beliefs, interest and belief were not correlated. PTs abilities to work with Mentor feedback appears to be impacted by interest and mathematical beliefs. Together with content-informed scaffolding, PTs who had interest and/or problem-oriented mathematical beliefs supported PTs to work with Mentor suggestions. Problem-oriented mathematical beliefs also appeared to support PTs to work with performance feedback.

Discussion

Content-informed scaffolding is scaffolding that encourages reflection, identifies and stretches a learner's thinking, and considers the content of the mentoring to be mathematical problem solving rather than the problem at hand. Mentors who provided performance feedback, in contrast, gave task specific directions in one of two ways. They either told students this is an area of weakness: fix it, or they told students you can make your performance better in this area by doing the following (e.g., reflect). Regardless of the type of mentoring PTs received, PTs were inclined to provide performance feedback to the elementary students. As evidence from prior study suggests, because the PTs' classroom feedback was performance feedback, the PTs did not have a model or a vision of content-informed scaffolding other than that provided by the online Mentors and the few examples in the OMG. This discrepancy may account for what appears to be the likelihood of PTs' ignoring or misunderstanding suggestions that were content-informed scaffolding. However, three trends emerge from these data suggesting the the possibility that PTs such as these can be supported through content-informed scaffolding to provide content-informed scaffolding: First, PTs in the content-informed scaffolding group demonstrated understanding of Mentor suggestions regardless of interest or problem-oriented mathematical beliefs more frequently than those in the performance-feedback group. Second, among PTs receiving content-informed scaffolding, higher interest PTs were more likely to make use of Mentor suggestions than lower interest PTs. Third, all PTs with problem-oriented mathematical beliefs were more likely to make use of Mentor suggestions than those with accuracy-oriented mathematical beliefs. It appears that productive disposition conceptualized as including interest and problem-oriented mathematical beliefs do impact readiness for scaffolding.

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Acknowledgements

We appreciate the assistance of Claire Meade and Annie Fetter of the Math Forum@Drexel and the participating PTs and their professors. This study was supported by the National Science Foundation (NSF Grant #9618223). Any opinions, findings, and conclusions are those of the authors and do not necessarily reflect the views of the NSF.

Time is precious: Why process analysis is essential for CSCL (and can also help to bridge between experimental and descriptive methods)

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Abstract: Although *process* is a key characteristic of the core concepts of CSCL—interaction, communication, learning, knowledge building, technology use—, and although CSCL researchers have privileged access to process data, the theoretical constructs and methods employed in research practice frequently neglect to make full use of information relating to time and order. This is particularly problematic when collaboration and learning processes are studied in groups that work together over weeks, and months, as is increasingly the case. The quantitative method dominant in the social and learning sciences—variable-centered variance theory—is of limited value, so we argue, for studying change on longer time scales. We introduce event-centered process analysis as a more generally applicable approach, not only for quantitative analysis, but also for providing closer links between qualitative and quantitative research methods. We conclude with suggestions on how nomothetic, idiographic, and design-oriented research interests can become better integrated in CSCL.

Goals

CSCL is concerned with technology-mediated learning as it takes place in groups. Independently of the context of the learning—on the level of the individual, the group, the situation, or in the interaction of these—the main object of analysis in CSCL is a process, something that unfolds over time. As Koschman (2001) suggested, it might be a defining element of CSCL that it is about "...studying learning in settings in which learning is observably and accountable embedded in collaborative activity" and that learning within these settings is to be conceptualized as an "unfolding process of meaning making" (p. 19). More recently, Stahl argues that one can meaningfully speak about group cognition as different from the sum of individual cognitions (Stahl, 2006). This is different from the psychological notion of learning as a basically unobservable process taking place in the mind/brain, a process we can observe only indirectly by measuring learning outcomes. However, for both views of learning, the socio-cultural as well as the individual-cognitive, the nature of the process remains: learning is a process that unfolds over time; hence order matters.

The analysis of processes becomes particularly relevant, but also more challenging, as the time frame considered for analysis grows. That CSCL is as much concerned with long-term collaboration as with short term collaboration can be seen from a short analysis of all empirical studies reported in the last CSCL conference (Koschmann, Suthers, & Chan, 2005). As Table 1 shows, the majority of studies analyze group interactions that extend beyond a couple of hours and almost 50% of the studies concern groups that learned together for more than a month (of course, the duration assessed is not commensurate to 'time on task').

Table 1: Duration of group lifetime in studies from the CSCL 2005 conference

"Lifetime" of groups studied	No. of studies	Percentage
Single session (20-180 minutes)	25	35%
2-6 days	5	7%
1-4 weeks	7	10%
Longer (1.5 months – 1 year)	34	48%
Total	71	

In studies where interaction and learning is distributed over multiple sessions, the research process does not only become more challenging for logistical reasons, but also because core assumptions of the experimental, treatment-oriented methods no longer hold. For instance, it becomes implausible that a treatment factor (be that a technical feature or a pedagogical measure) is acting *continuously* over time, an assumption that is fundamental to any experimental design and statistical method related to analysis of variance. Furthermore, 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 experimental 'unit'. Order effects as well as non-linear changes will become more pronounced because of the self-sustaining feedback processes at work in groups over time (Arrow, McGrath, & Berdahl, 2000). All of these problems constitute serious challenges for any theory and method that either ignores time completely or is based on the variance analysis model.

These challenges might partially account for the fact that although CSCL researchers are privileged in the sense that they have access to processes as they unfold over time, there is comparatively little research that makes use of the information contained in the order and duration of events. As a case in point, by my count only one study (Kapur, Voiklis, & Kinzer, 2005) out of 71 from the 2005 CSCL conference made use of statistical analysis methods that take time into account. Not only is the information contained in the order of events unused, there is also the risk that the results found using data subject to order effects are of limited value when order is ignored.

Since this is certainly not an ideal state of affairs, this paper sets out to accomplish two goals. The first goal is method-oriented: to provide the reader with some information on how sequential analysis can be conducted and appropriate methods that may apply, in particular for cases where the duration of group processes is long. This will be kept short, though, because good introductions into sequential data analysis exist (e.g., Sanderson & Fisher, 1994).

The second goal is a methodological one: This paper can be seen as continuing the discussion started by Dan Suthers (2005) on What To Study in CSCL research and How to Study It. With respect to the What, he suggests that research on "…processes of intersubjective learning, and how technological affordances mediate or support such processes" be privileged (p. 669). With respect to the How, he proposes hybrid methodologies that combine the strengths of experimental, descriptive, and interactive design approaches. However, integrating methods from such diverse paradigms is challenging due to the tensions arising from the differences in research interests. Experimental methods (along with analysis of variance as the predominant statistical method) have been developed in the tradition of the nomothetic, 'law-searching', quantitative paradigm, while Descriptive and Design approaches can be seen as variants of the idiographic, qualitative paradigm. While idiographic methods can make important contributions to improving computer tools and pedagogical designs, their contribution to theory building and testing, i.e. the nomothetic research program, has often been challenged (Goldthorpe, 2000).

I attempt in this paper to identify ways in which, for the field of CSCL, descriptive and experimental methods can be best aligned, starting from a discussion of the obstacles a purely variable-centered approach (of which the Experimental Method is an instance) faces for theorizing and analyzing change and learning processes in groups. Building on a reconsideration of what should count as process and process analysis, *event analysis* is suggested as most appropriate for law-searching research in CSCL because it can deal with change processes of various forms, provides a research logic that integrates qualitative-descriptive with quantitative-nomothetic accounts, and is at least somewhat informative in the design of software tools and pedagogical strategies.

Variable-centered Process Analysis

In order to illustrate our discussion, let us sketch a hypothetical, but prototypical scenario. The situation that we want to address is one where the researcher is interested in interaction and learning processes as they take place in on-line groups over time. The researchers want to test a process theory, one that says that groups need to go through a cycle of definition, conflict, and synthesis repeatedly in order to successfully engage in and learn from discussion activities. Therefore, they have developed a coding scheme that can be applied to the content of the discussion board entries and categorize them in respect to the three dimensions. The coding scheme is developed and applied following best practice (e.g., Strijbos, Martens, Prins, & Jochems (2006)). Let us further assume that the researchers are interested in design issues pertaining to the visualization of argument threads. For this purpose, they have developed a new version of the discussion board, one that includes a graphical display of the argument structure.

Our hypothetical research team has access to students in an on-line university course who are working together in several small groups. About half of the groups work with the old, run-of-the-mill discussion board, whereas the other half of the groups uses the new version. Data are recorded electronically in the form of the discussion board log file, so that we know who contributed what and when. Pre- and post-tests are conducted to assess individual learning gains and during the pre-test phase a number of other individual factors are assessed, including metacognitive capabilities. As outcome measures, individual learning is assessed with a pre- and post-test, and knowledge building is assessed by analyzing the discussion board entries.

How these data are analyzed will depend largely on what the researcher considers a process to be. Two conceptualizations of process will be distinguished here. The first one, *variable-centered*, relates to analysis of variance (or, as we prefer to call it, the *variance method*, because it includes the design of experiments, not only the analysis of data). The second one with roots in historical and organisational research, is called *event-centered analysis* or *event analysis* for short. I use the terminology suggested by Abell (1987) and in particular by Poole, van der Ven, Dooley, & Holme's (2000) excellent treatment of process analysis in the social sciences informed many parts of this paper.

For the experimentalist, being trained in the variance method, a process takes the form of a *category of concepts* that mediate between independent and dependent variables. In CSCL, variables such as communication frequencies, learning techniques, and group decision making techniques can play this role. Such 'process concepts' are distinguished from other concepts considered to be static, such as individual learning capabilities, group makeup, or learning outcomes. A process theory for the experimentalist takes the form of a causal relationship between income and outcome variables mediated by process variables. The process concepts, like the static concepts, are operationalized as constructs and measured as variables, as fixed entities, the attributes of which can vary from low to high along numerical scales. A typical question that could be analyzed with this framework is the extent to which individual learning skills (exogenous independent variable) can predict learning outcomes (dependent variable), dependent on more or less successful group communication (endogenous independent variable).

For our scenario, the initial analysis would be fairly straightforward: The experimentalist would "code and count": code the data stored in the discussion board log, and count, yielding frequencies for the process categories (definition, conflict, synthesis). Then these measures can be set in relation to the treatment (tool variation) as well as in relation to other variables assessed, in particular to the dependent variables: individual learning and group knowledge building. A typical analysis of variance would yield results that show if the difference in the dependent variables can be related statistically to the variation in the tool, if this relation is mediated by the process variables, and if there are (statistical) interactions with the other variables assessed (for instance, metacognitive competence).

In order to test the process theory in more detail— which says that we should see, in successful groups, cycles of issue definition followed by conflict among positions followed by synthesis/integration of positions— the researcher could treat each of these categories as a variable, using the categories frequencies assessed at regular intervals (daily, say) as the quantitative attribute, and treat them as three time series. For each individual time series, curve fitting can be performed to test if they form a sine wave—as they should if the assumption of 'repeated cycles' is correct. Having established this (and, before that, having established that the time series variables follow approximately a Gaussian distribution), the researcher could go ahead and use multivariate time series (ARIMA) models to test the dependencies between the three time series (they should follow each other and 'peak' with a certain time lag, but in the order definition-conflict-synthesis) and to test if and to what extent extraneous factors, in particular the type of discussion board, affect the time series. Based on the same logic, one could also look for the effects of differences between groups (using a criterion for 'successful' and 'less successful' groups, for instance) and for differences between individuals (using metacognitive competence as a criterion, for instance).

There is neither need nor space for statistical details here (see e.g., Box & Jenkins, 1976). Instead, a word on the assumptions behind the variable-centered research method may be in order. A basic assumption that underlies any research logic based on the analysis of variance is that independent variables are acting continuously on the dependent variables. I would argue that this basic assumption is for CSCL often not met. Obviously, students in our scenario will, over the duration of the semester, do many things other than the type of activities captured by the measurements. Even when they are actively engaged on-line, only a small set of the factors represented as independent variables might be effective at any point in time; for instance, the students using the enriched discussion board might not attend to the information offered on the visualizations. This *fragmented* nature of the underlying causal processes is not easily captured in variable-centered models. Another thorny problem in process studies arises from the fact that all variables must be measurable at the same time point, and the temporal unit or measurement must be equal for all variables (*minimal unit of time*). Since we will find, in any group, processes unfolding on different time scales (McGrath & Tschan, 2003), relating them in one model is a challenge indeed. And as was mentioned before, the variable-centered method cannot accommodate qualitative changes in the variables. For instance, when a group loses a member or gets a new member, it is not clear if variables that build on group activities can be considered to be qualitatively the same than before.

The main argument I want to put forward is that, for situations similar to our scenario, which is typical for CSCL research, the variable-centered approach is of limited value, and needs to be extended by an *event-centered approach* that can more comprehensively account for the change processes under study in CSCL. Not only do I argue for event analysis because it adds important information to our understanding of learning and change, I also argue that it offers a bridge between qualitative and quantitative research methods, a bridge that seems particularly valuable for CSCL where research is conducted in both traditions.

The Event-centered Approach to Process Analysis

Our short sketch of the event-centered approach builds on Abbott (1990) and Abell (1987; Abell, 2004), who, among others, noted the differences between scientific explanations cast in terms of independent variables causing changes in a dependent variable, and explanations that provide a narrative in order to explain how a sequence of events unfold to produce an observed outcome.

The limitations of the variable-centered approach (in the social sciences) to describe change processes are mainly due to a restricted view of causation. Independent variables are seen as 'acting on' dependent variables; the underlying process is supposed to operate continuously over time; the nature of the variables does not change over time—all that can change are the values of the quantitative attributes used to operationalize the variable—and no qualitatively different kinds of forces are deemed necessary to explain changes in the dependent variables. If too much variance remains unexplained, one has to look for additional independent variables and/or include specifications of relationships (statistically: interactions) between the variables. The underlying notion of causality is *efficient causality*, the 'push' type causality that has been so instrumental for theories in physics.

To account for group (and in general, for social) phenomena, a process method should, in addition to *efficient cause*, be able to deal with at least two other kinds of causes (of the four Aristotle identified overall (Aristotle, 1941)), namely: *formal* cause, referring to the patterns of which things are made, and *final* cause, the end for which things are made (i.e., teleological 'pull'). In groups, formal causality is at work whenever constraints —as imposed on them in terms of workflow, scripts or roles—are effective. For instance, many events taking place in on-line learning groups are a consequence of the manner in which groups have been set up (scripts, roles, workflow, deadlines). In organizations, the way team members interact with each other and with other teams is to some extent affected by the organizations' design and their business processes, all best captured as *formal cause*, and not requiring reduction to efficient causes (where the invariants and the explanatory power would be lost because many efficient cause processes can instantiate a single formal cause relation). Similarly, explaining human behavior (in various levels of aggregation: individuals, pairs, groups, and larger structures) in terms of *goals,* i.e. driven by an *end,* adds considerable explanatory power, in particular for the (rather typical) cases where a goal can be reached in many different ways. Any account of these different paths towards an end in terms of only efficient causality would fail to identify the goal orientation.

The event analysis approach to be introduced now encompasses all three kinds of causality: efficient, formal and final. (As we don't go 'down' to the neurological level, we leave out Aristotle's fourth type, *material* cause, for explaining individual and group behavior.) A pivotal difference to the variable-centered method is that event analysis does not start by framing 'the world' in terms of variables, i.e. fixed entities with varying attributes. Instead, event analysis "...conceptualizes development and change processes as sequences of events which have unity and coherence over time" (Poole *et al.*, 2000, p. 36).

What counts as an event is basically up to the researcher, constrained by theory and informed by research goals; events are not 'raw data', or incidents. In particular, events need to be defined dependent on the identification of the *central subject* under study because *entities participate in events*. The central entity in event analysis is some kind of actor, but the actor does not have to be a person; it can also be a group, an organization, a nation, an idea, a technology—dependent on research question and disciplinary background.

In our scenario, the main entities are individuals and groups. That implies then that events are constrained to those incidents in which either individuals or groups can participate. For our scenario, a process researcher would focus on the sequences of activities, incidents, crises, or stages that unfold in the groups over the duration of the semester. An explanation for an observed chain of events would take the form of a narrative that explains how event e(t) is related to events e(1) ... e(t-1) in terms of the actors' goals, motives, moves etc. and would keep track of how events happening outside the groups might affect them. The process is conceptualized here as a *developmental event sequence*, not a change in values of process variables. The research process yields a narrative for each case, a case being a single person or a group, dependent on the level of analysis chosen. We note further that in *narrative* *explanations* the three types of causality are usually combined (Abell, 1987). The format of a narrative explanation is not only used by people when explaining other peoples' behavior, but also frequently employed by social scientists, for instance historians and political scientists.

We will not go into more details with respect to event coding here, because this kind of content analysis is well understood and has recently been the subject of methodological reflection in CSCL (Strijbos, Martens, Prins, & Jochems, 2006; Wever, Schellens, Valcke, & Keer, 2006). However, it is important to keep in mind that events are *not* treated as variables in event analysis, i.e. they are not aggregated (by coding category) into counts. Correspondingly, the process researcher does not look for co-variance between the values of independent and dependent variables, but "explains outcomes as the result of the order in which the events unfold and of particular conjunctions of events and contextual conditions" (Poole *et al.*, 2000, p. 36). The explanation takes essentially a *narrative* form and works with a *historical* logic: In order to explain any event in the scope of the study, that event will need to be related to events that took place (potentially a long time) before, not only to contextual factors (such as tool variation in our scenario). The order in which events occur and the conjunctions between different lines of events are essential to narrative explanations. Dan Suther's recent analysis of 'uptake' actions (2006) can be seen as an instance of such a type of analysis applied to a collaborative learning situation.

In addition to formulating such narratives for the change processes observed in the cases under study, the process researcher can test *general* theories, i.e. add a nomothetic dimension. This, as well as the use of quantitative methods, distinguishes event analysis from purely descriptive methods, such as ethnomethodology (Garfinkel, 2002) and conversation analysis (Schegloff, 1996). Generalizations are performed in two ways. Firstly, by identifying general, prototypical event sequences; looking across the event sequences from a number of cases (*all* groups in our scenario study), a process researcher would look for sequences or cycles that occur within and across groups with some regularity. Secondly, process research of this kind entails the need to account for the observed (sequence) regularities in terms of *generative mechanisms*, in terms of "motors" that "drive" change. To the extent that these generative models can themselves be related to a typology of classes of change models, generalizations can be performed not only on the level of sequence descriptions, but also on the level of generative theories/models. To give an example for such a typology: van de Ven & Poole (1995) have developed a typology of process theories that identifies four (ideal) types of theories of social change: (1) life cycle (e.g., Piaget's stage model of ontogenetic development); (2) evolution (e.g., Darwinian evolution in biology); (3) dialectic (e.g., Dialectical Materialism in economy/history), (4) teleology (e.g, Mead's Symbolic Interaction theory in sociology). To the extent that this typology is complete (for social sciences), any specific generative account for a change process can be expressed as a variant of one of these theory types, or as hybrid model: a combination of two or more of the theory types.

To relate this to CSCL: most of the change processes observable in on-line learning groups will incorporate elements of a life-cycle motor because groups will comply to some extent with the pedagogical or experimental design imposed on them. In addition, they might incorporate elements typical for a dialectical motor, for instance in settings where argumentation is important (Wegerif, 2005), or elements of an teleological motor, for instance for groups where problem solving is the main task (Zumbach, Hillers, & Reimann, 2003). An evolutionary motor may be found in groups that deal with design challenges (Kolodner *et al.*, 2003), for instance.

Independently of how appropriate one considers a specific combination of change motors to be for specific observations (an empirical issue), the point we want to make here is that the framing of a specific model in terms of more fundamental (generative) theories— for instance in terms of the four families of change theories—constitutes a powerful explanatory strategy, well aligned with—if not prototypical for—the scientific method in general. Unlike variance theory event analysis can deal with change where there is no consistent 'push' force and where the entities under study change qualitatively over time (are not uniform). While for the variable-centered approach generality depends on *uniformity* of the identified relation between variables across contexts and cases, a event approach theory aims for *versatility*, "...the degree to which it can encompass a broad domain of developmental patterns without modification of its essential character" (Poole et al., 2000, p. 43)

The reason process theories can be considered to be closer to the causally effective processes has to do with the definition of events as those incidents that are enacted by and happening to the central subject. This is a central feature of narrative explanations (Abbott, 1988). Narrative explanations apply also to situations where not only attributes of entities (central subjects) change, but the entity itself changes— for instance, through transformation into a different entity, through division, mergers, or dissolution. For CSCL research, where a group will more often than not be the central subject under study, this flexibility is a great advantage because it allows us to deal with all those change processes that affect a group qualitatively, such as changes in membership or major changes in groups' mission. For variable-centered theories, changes in the qualitative nature of variables are a non-issue: we would no longer measure the same (latent) concept. Of course, any method allowing for qualitative change of the central subject needs to find a way to distinguish between what constitutes a 'legitimate' qualitative change (that needs to be accounted for by theories dealing with that central subject) and the case where a theory no longer applies. Historians, where narrative explanations are ubiquitous, have found ways to deal with this challenge by explicating the idea of a *coherent central subject*, making not similarity, but spatio-temporal continuity the criterion: "...for any historical entity to remain the same entity, no degree of similarity between earlier and later stages in its development is required, as long as this development is spatio-temporally continuous" (Hull, 1975, p. 256).

Quantitative Methods for Event-centered Theory Testing

Although generalizing across cases and testing generalizations against cases does not require statistical methods (see for instance Abell (1987) and Heise (1990) for alternatives), we will only discuss the statistical methods in order to continue the comparison with the variable-centred method. An element of probability needs to be introduced when we move to testing general models. The reason for this is that predicting singular events based on a deterministic model requires the assumption that all factors other than those included in the deterministic model are constant. This is not realistic in most cases in the social sciences, certainly not in the situation considered here with a minimum of experimental control and a long duration.

Event analysis does not reject quantitative methods. Quite to the contrary, they form an important element for the purposes of generalizing across cases and testing process theories. Event analysis makes use of statistical methods that are appropriate for event data, i.e. do not require the data to be represented as variables. An example for such *stochastic* methods is Markov Chain modelling. Stochastic modelling methods have a fairly long tradition in the social sciences and psychology (e.g., Coleman (1964); Suppes & Atkinson (1960)), yet are not as widely taught and used in learning research as are variance analysis methods and other members of the General Linear Model family.

This is not the place to introduce stochastic modelling in any detail, but in order to provide a flavour, a simple example might be appropriate. Let us again assume that we want to test if the life cycle model that presupposes that (successful) groups will go through a cycle of Definition-Conflict-Synthesis is supported by the data. One can also see this as a dialectical model if the cycle is not imposed on groups by the pedagogical design or strongly afforded by tool design but emerges out of the interactions. We could have coded incidents directly in these terms, yielding a event sequence in each group of a form like DDDCCDCCSCCSSSS… , with D for Definition, C for Conflict, S for Synthesis. To test if this mini-theory describes the behavior in the groups adequately, one could use a Markov Chain model. Markov chains belong to the class of homogenous Markov models, which are appropriate for cases where time can be considered as consisting of discrete intervals and where the only aspect we need to know about an event is when it was present in time. Being stochastic, Markov models do not predict the occurrence of a specific event, but predict the probability distribution of a set of possible events at a given point in time. The Markov chain predicts the probability of occurrence of an event at time t as a function of the events occurring immediately before. No other information is taken into account.

A more complex, but also more realistic case is one where we do not define events in terms of the comprehensive descriptors (Definition, Conflict, Synthesis) directly, but code on a finer level of analysis. For instance, we could code the interactions in the groups with a taxonomy that is inspired by speech act or dialogue act theory (adapted to the asynchronous case). We would use, say, a coding scheme with 12 different categories, c1 to c12 (omitting any further details here). We would then look at sequences in the groups of the form like …c3c1c1c5c3c12c3c6c6c6c1c2c6…. To test our mini-theory of the three phases in this case, phasic analysis (e.g., Holmes (1997)) could be used, or Hidden Markov modeling (Rabiner, 1989).

These matters can not be discussed further here (see Soller, Wiebe, & Lesgold (2002) for an example of Hidden Markov modelling in CSCL). Suffice it to say that further generalizations of Markov models have been developed. For instance, nonhomogeneous Markov processes add variables other than the events to the model. With them, we could test if the two tool conditions (conventional vs enhanced discussion board) make a difference, or if individual differences add predictive power. So called semi-Markov process models allow information about the *duration* of events to be included (still assuming discrete event time, meaning that events do not have to form a continuous stream), information we sometimes have available in log files. Finally, Markov modelling has been generalized to deal with continuous time.

A question we have not tackled yet is: Where do the process models come from? No surprises here, at least for those researchers who work nomothetically: from theory. One should have theory-based expectations as to the changes one would expect in groups before one engages in an empirical study. Of course, after testing the theory-driven hypotheses, few researchers would resist exploring if there are other interesting change processes hidden in the data. Identifying interesting new narratives that apply to event sequences not (adequately) covered by the theoretical expectations will often need to be done by researchers 'manually'. To some extent, data mining methods can help in this inductive phase. Kay, Maisonneuve, Yacef & Zaiane (2006), for instance, present a nice example of how applying a data mining algorithm (the Frequent Sequential Pattern algorithm, first introduced by Agrawal & Srikant (1995)) to more or less unprocessed (at least not human-coded) log file data covering students' long-term interactions in a realistically complex socio-technical setting can result in interesting discoveries. In this case, systematic differences between successful and less successful teams in (asynchronous) interaction sequences where found in a corpus of about 10.000 incidents.

Combining Variable-centered and Event-centered Methods

For the purpose of clarity, I have juxtaposed the variable- and event-centered methods, focusing on their differences and ignoring their commonalities. The main commonality they share is their nomothetic character; like with variable-centered methods, event analysis can be used to test law-like explanations. (For a deeper analysis of the fact that variance explanations are preceded by generalizing, whereas narrative explanations logically come before (optional) generalizing, see Abell, (1987) The criterion for generality is different, though (versatility instead of uniformity). Like the variable-centered approach, event analysis incorporates quantitative methods and embraces probabilistic concepts. Indeed, event analysis can be said to be *more* quantitative than the variable-centered approach because it aims to apply mathematical methods to phenomena where not only effective causation is at work, but formal and final causation as well. This suggests, despite the many differences, that the two methods can also fruitfully be combined, forming a general process analysis method.

The variable-centered, variance-oriented approach works perfectly well for research questions that involve relationships among variables. An event analysist has nothing against variables, as long as they are not seen as the *only* way to describe and explain change. We already mentioned that stochastic event sequence analysis can incorporate information that takes the form of values of variables by employing non-homogeneous Markov models. But the potential for method integration is not exhausted here. While process analysis makes use of stochastic modeling methods because they use event type directly and thus preserve the nominal character of events and the integrity of event sequences unfolding over time, it can also employ *event variables*. Event variables are quantitative aspects of events, such as duration and intensity, or any other quantitative dimension that can be associated with an event. For such variables, variants of time series analysis (see above) can be used. Finally, variables can be used in process research that describe the *characteristics of event sequences*, such as their periodicity, and these variables can figure as independent or dependent variables in theories of how such characteristics affect outcomes or are affected by other factors, respectively.

Since event analysis is more of a generalization of, rather than an antagonist to, the variable-centered method, experimental design with its meticulous control of external variables can be integrated. This is important for CSCL when we are interested in experimental trials of pedagogies and technical tools. There is no reason why such treatments should not be realized and included in process analysis, both in its narrative part as well as in the statistical analysis. What event analysis reminds us, though, is that we should not harbor overly simplistic assumptions as to the causal relations between such treatments and groups' behavior, in particular when groups interact with technology over longer stretches of time. Table 2 summarizes the research steps that are shared and unique, respectively, between variable- and event-centered approaches.

Conclusions: What is gained?

Starting from the observation that the analysis of change processes—in individuals in the form of learning, in groups in the form of participation and knowledge building—is a central concern for CSCL and that CSCL researchers have privileged access to detailed change data, we have noticed a lack in the use of (quantitative) methods that take the core dimension of change—time—into account. This is a particular concern in light of the fact that the majority of studies conducted in CSCL—if we take the 2005 conference as representative—deal with change processes that have a duration of weeks and months. If individual and group processes are analysed on such a scale without taking into account history, sequence, dynamics, in short: time, then many of the resulting findings are of limited value. We argued further that for studies that aim to analyse change unfolding over days, weeks and months, the quantitative method dominant in the social and learning sciences—variable-centered variance theory—is of limited value, not only because of the problems arising from 'controlling' extraneous variables over longer stretches of time, but more importantly because of problems with the fundamental notion of variable, and process. We introduced a general process approach that builds on the notion of narrative explanations. I identified the main differences between variance and event analysis, provided arguments why the event analysis suits the need of CSCL research better, and concluded with an illustration of the type of quantitative analysis the event analysis allows, in addition to the many features it shares with qualitative methods.

Table 2: Method integration

<table>
<tr><th colspan="2">Nomothetic</th><th>Idiographic</th></tr>
<tr><th>Variable-Centered</th><th>Event-Centered</th><th></th></tr>
<tr><td colspan="3">Research design</td></tr>
<tr><td>Operationalisation of theoretical constructs into variables</td><td>Identification of central subject(s); definition of event types; Optional: Definition of variables</td><td>-/-</td></tr>
<tr><td>Realisation of Treatment Conditions</td><td>optional</td><td>-/-</td></tr>
<tr><td>Randomisation</td><td>optional</td><td>-/-</td></tr>
<tr><td>Control of external factors</td><td>Optional; Recording/Documentation of changes in the environment of the central subject</td><td>-/-</td></tr>
<tr><td colspan="3">Data analysis</td></tr>
<tr><td colspan="2">Coding: Classification of events</td><td>Optional</td></tr>
<tr><td>-/-</td><td>Establishing of narrative explanations for sequences and conjunctions per case</td><td>Qualitative, often narrative, "thick" accounts</td></tr>
<tr><td>-/-</td><td>Identification of patterns in sequences across cases</td><td>Optional</td></tr>
<tr><td>-/-</td><td>Identification of change motor</td><td>Optional</td></tr>
<tr><td>-/-</td><td>Stochastic Modelling</td><td>-/-</td></tr>
<tr><td colspan="2">Aggregation of codes into counts</td><td>-/-</td></tr>
<tr><td colspan="2">Analysis of Variance</td><td>-/-</td></tr>
<tr><td colspan="2">Time Series Analysis</td><td>-/-</td></tr>
<tr><td colspan="3">Reporting</td></tr>
<tr><td>Variable-related</td><td>Case-and variable related</td><td>Case-related</td></tr>
</table>

CSCL research can gain from an adoption of process methods in a number of ways. By the adoption, group process research gets a sound methodological foundation, descriptive and experimental approaches can be better integrated, and information informative for design can be derived. As has been the main argument on these pages, the variable-centered method, dominant in most experimental learning research, is not the best (nomothetic) method for conducting process research in CSCL. It makes too restrictive assumptions on the kind of data useful for analysis (namely variables only) and on the kinds of causation allowed to explain change. Adapting the more general stance to process analysis described above, we gain a more widely applicable yet by no means less rigorous method to analyse group processes.

Event analysis holds the potential to provide a methodological link between those researchers in CSCL who are producing descriptive, "thick", interpretive accounts of observations on learners' computer-mediated interactions, and those in the research community who work experimentally and quantitatively. The link results mainly from the fact that the event-centered approach makes extensive use of event descriptions: they enter into narrative accounts and, optionally, into statistical analysis without loosing their distinctiveness. Hence, independent of the research orientation (nomothetic, idiographic, design-oriented), activities such defining, identifying, distinguishing events and event sequences as well as providing qualitative, narrative accounts of events and sequences are part of a common set of research activities and become shareable. The fact that there are many common elements to the research 'work' across different epistemological orientations is better exploited than is the case for variable-centered methods (see also Table 2).

By the same token, the event-centered method can contribute substantially to design-oriented research. A comprehensive, detailed descriptive account of how individuals and groups interact with technology over time is an important component to inform software designers in the early stages of the development process, and it provides opportunities in the trial phase to gauge for (positive as well as negative) side effects of introducing tools and technologies. An example for the value of employing (qualitative) process studies for information technology design is the research on structuration and appropriation processes (Poole & DeSanctis, 2004). But it needs to be said that this line of research has less implications for interface design than for organisational design and change management.

However, understanding organisational change processes and how they affect and are affected by collaborative technologies will become very important when (and if) CSCL follows the proposal that CSCL needs to concern itself more with processes that take place on a *meso level*, a level "...intermediate between small scale, local interaction and large-scale policy and institutional processes" (Jones, Dirckinck-Holmfeld, & Linstroem, 2006, p. 37). In general, when collaboration tools are used over extended periods of time, as they increasingly are due to the ubiquity of technology for collaboration and learning, then knowledge about how our technologies and tools affect individuals and groups over time becomes essential. As we move out of the laboratory and provide people with tools for their daily use, some of the most interesting processes are those that unfold over time (such as appropriation moves). They are not observable in the usability lab or the short-term study looking into immediate (learning) effects. Analysing the effects of specific tool and design decisions over longer stretches of time is also important for a realistic assessment of costs and benefits; for instance, Zumbach & Reimann (2003) observed that providing feedback to group members on interactional aspects was much more effective in the early stages of groups' lifetime than later and that, hence, this information should be phased out over time in order to reduce the cognitive load (the 'costs'). Still, the contribution to design, in particular to 'interface' design, is the least satisfying aspect of the strategy for method combinations suggested here. While researchers both in the nomothetic and idiographic tradition might appreciate some of the suggestions, the Great Unified Methodology for CSCL that pays due respect to all three epistemic orientations—nomothetic, idiographic, and design-perspective—is not identified here.

Time is indeed precious. Too precious to be ignored or not treated adequately when formulating and testing theories of working and learning collaboratively. But the time of CSCL researchers is also precious; process studies are very work intensive, thus any method that can help us to share the workload and to conduct research cooperatively across epistemic interests and paradigms, without forcing us to gloss over fundamental differences, should be welcomed by the field. As a side effect, shared on-line collections of (annotated) sequence data could be created that can be analysed from multiple perspectives and with various methods or tools. The time gained might be most profitably be spent on developing generative process models and theories, of which there is a genuine lack in CSCL.

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Acknowledgements

I would like to thank Anindito Aditomo for conducting the duration analysis on the CSCL 2005 conference papers, and him as well as Rob Kildare for providing me with feedback on earlier versions.

Engaging Students in Science Controversy Through an Augmented Reality Role-Playing Game

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Abstract: POSIT (developing Public Opinions on Science using Information Technology) is an augmented reality role-playing game for networked handheld computers. It is designed to improve engagement in science controversies and develop skills in evaluating evidence and forming arguments. Groups of high school or college students investigate a scenario based on a fictionalized science controversy. They gather evidence from virtual characters and items situated in real locations and compete to develop the most persuasive arguments. Preliminary results suggest that this is a promising approach and further design experiments are needed.

Introduction

Increasingly, we are faced with science controversies that have broad implications for society. Students need both greater engagement in the science controversies that affect them, and better tools to evaluate evidence and form arguments. Here we report preliminary design experiments with a game aimed at meeting those needs.

POSIT (developing Public Opinions on Science using Information Technology) is an augmented reality role-playing game for networked handheld computers. Groups of high school or college students are introduced to a scenario based on a fictionalized science controversy, gather evidence about it, and rate each other on their arguments.

POSIT builds on previous technical and pedagogical work with augmented reality games. We have chosen to situate the game and the players in the real world using handheld augmented reality technologies, because we have seen in previous work creating such games outdoors (Klopfer & Squire 2006) and indoors (Rosenbaum, Klopfer & Perry 2006) that information from real world surroundings plays an important role in decision-making. Studies of other augmented reality games have shown for example that students can become strongly engaged in their simulated worlds (Facer, 2004), and can synthesize and evaluate evidence within the game in sophisticated ways (Schrier, 2006).

The design of POSIT also builds on related work using technology to track student opinions (Yoon, 2006) during discussions around controversies in science. Yoon's work demonstrated the importance of providing tools for students to reflect on their own opinions and that of their peer groups. There are also non-technological games that influenced the design of POSIT, including Democs (Smith, 2005), a card-based activity which engages small groups in debating public policy issues.

Research questions

While POSIT is the center of a larger research program, for this initial study we chose to focus on two particular questions of interest:

1. Does POSIT engage students' interest in a science controversy?
2. Does POSIT lead to improvements in the skills of evaluating evidence and forming arguments?

Game overview

In our initial scenario, players face the question: "Should the University build a BSL-4 lab?" BSL-4 is the highest bio-safety level, required for the study of the most deadly pathogens. Players are given a briefing on the game the day before, then a short introduction on the day of the game. They play the game for 2 hours. Partway through the game and again at the end players meet and form pairs in order to rate each others' arguments. At the end of the game, there is a wrap-up discussion.

Each player is randomly assigned one of ten roles, including a brief description of their background and their potential stake in the proposed lab. These include a university student who lives near the proposed lab site, a local parent, a city councilor and a biotechnology executive. Players enter their opinion on the question using a slider that ranges from -5 (no, the university should not build the lab) to +5 (yes, it should). A dynamically updated histogram allows them to see the opinions of the other players.

Players walk to various buildings on campus in order to gather evidence. The handheld device detects which building the player is in and displays the relevant game content. An actual construction site on campus represents the proposed lab site.

A variety of virtual characters representing a range of opinions are distributed throughout the buildings in the game. They are situated in realistic locations (e.g. there are virtual students in the actual dorms and virtual nurses in the actual medical center). Players can "interview" them to get textual responses with their opinion on the controversy. Virtual items such as newspaper articles, journal articles, technical documents, informational pamphlets, photographs and advertisements are distributed among various locations. News flashes, text messages and other bulletins arrive at fixed times, to a subset of players according to their role. This dynamic content is used to create story lines that develop through the course of the game.

Players can select the most persuasive evidence they have gathered (items, announcements and responses from virtual characters) and add it to their "evidence portfolio." To receive scores, players form pairs in which one player rates the other's argument. The arguer sends her evidence portfolio to the rater, allowing the rater to examine it. The arguer delivers a brief verbal argument, and the rater gives her a score according to a three-part rubric (basis of the argument in facts, relevance of the argument to the arguer's role, and response to a rebuttal).

Research Methods

POSIT is currently being pilot tested with high school and university level students. Formative evaluation surveys, and video of game play and focus groups discussions are currently being analyzed. Additionally, a pre/post transfer test to assess skills in forming arguments has been pilot tested.

Results

During pilot tests we observed that students were able to manipulate the POSIT user interface, gather evidence, and present their arguments to each other. Students were engaged in the fictional scenario content, and appeared to understand how to play their roles and how to rate each other's arguments.

On surveys, students reported enjoying the story lines and "news flashes." Aside from technical glitches, they disliked walking around a lot, having to read messages that were too long, and receiving inaccurate ratings from their peers. We hope to address these problems with more densely placed game locations, shorter texts and the addition of videos, and improved game mechanics.

Some students also reported that the rating system helped them improve their arguments because e.g. it "made you realize some things did not back your argument as much as you thought," it "made people have to back up their ideas" and it "[made] your argument stronger and efficient." Some students reported changing their opinions on the controversy due to testimony from virtual characters. For example: "reading the messages from the characters helped me view different perspectives of these characters like the firefighter, Molly [etc]." Some students were affected by the physical situation of the proposed construction site in forming their opinions. For example: "I saw the spot where the building was set to be built on and it was very scary how many students and people walked by it constantly."

Analysis of the pre/post test suggests that after playing the game students form more arguments that are better based on facts and more representative of a role. Additional studies with a larger number and variety of students will be needed to clarify these results.

Future Directions

The game mechanics have evolved throughout our pilot tests. In an initial version, the game was primarily focused on players' opinions. The goal was to sway your fellow players toward your position in order to affect a vote at the end of the game. The incentives for gathering evidence and attempting persuasion were insufficiently clear. In our first attempt to give players a clearer goal, we created a simple dynamic opinion model for the virtual characters, so that players could "persuade" them. Players could send their evidence portfolio to virtual characters in order to change their opinions. If the portfolio contained highly persuasive evidence that had not yet been "seen" by the virtual character, its opinion would change. The virtual characters would then also participate in the vote at the end of the game.

To increase the focus on players interacting with each other (instead of only persuading virtual characters), we introduced the argument rating system described above. This system gives players a clear incentive to pair up and deliver verbal arguments, and gives immediate feedback in the form of a score. One problem with this system is that it does not prevent unreliable ratings, including cheating. To partly mitigate this we divide the students into two groups; within groups they compete for highest argument score, but they only give each other rating scores across groups.

In future tests we hope to evolve the argument rating system to further clarify the game goals for the player while rewarding effective argumentation techniques. One possibility is to give each player a "weakness," which is the category of argument to which they respond (e.g. scientific or emotional). Players are rated according to how well their argument matches the rater's weakness. This adds the elements of considering the audience when formulating an argument, selecting evidence to match argument categories, and using evidence flexibly to make different types of arguments.

Conference Demo

The demonstration will include a playable demo version of the game running on several handheld computers. In the demo version, most game functionality and content is available, without the wireless location-awareness feature. Video of students playing the game will be available as well.

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Acknowledgements

This project was supported by the Microsoft-MIT iCampus initiative.

How Does Net-Based Interdisciplinary Collaboration Change with Growing Domain Expertise?

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Abstract: This study examined how growing domain expertise influences net-based interdisciplinary collaboration of persons with medical and psychological background. We compared the quality of the collaborative process and the joint solution of interdisciplinary dyads of different expertise levels (advanced students, trainees, and experts) working on a patient case. To assess the quality of the collaborative process, a rating scheme developed by Meier et al. (in press) was used. Additionally, process log files measuring individual and joint time and number of work phases were gathered, and joint solutions were analyzed. As had been assumed, the experts scored lower than the less experienced dyads in most measures of collaborative process. Looking in more detail at the less experienced dyads revealed that the trainee dyads outperformed the student dyads in most of the process variables. Analyses of process logfiles revealed the same pattern regarding the number of phases used. The predictions for the quality of the joint solution were more difficult and the results for these variables more mixed.

Introduction

Studies on expertise development in different domains have revealed how experts' knowledge and the ways they solve domain-specific problems differ from those of novices (Feltovich, Prietula, & Ericsson, 2006). Also, it was shown that expert knowledge and problem solving behaviour differ across domains. Against this background, one would expect that experts from different domains should also differ in their interdisciplinary *collaborative behaviour* from laypersons or intermediates when asked to solve complex problems in a team. But even though interdisciplinary collaboration among experienced professionals is increasingly becoming important for solving complex problems in society, economy, and science, studies investigating social and cognitive processes of interdisciplinary collaboration are rare (Bromme, 1999). Existing articles primarily describe informal studies on successful and unsuccessful aspects of interdisciplinary work observed in the field (e.g. Epstein, 2005) or propose models intended to enhance such collaboration (McDaniel, 1995). The central question of the present study was, how growing domain experience influences net-based interdisciplinary collaboration. Two strands of research have motivated this study. First, in the last six years our team has investigated the net-based interdisciplinary collaboration among students of psychology and of medicine (Hermann, Rummel, & Spada, 2001; Rummel & Spada, 2005; Rummel, Spada, & Hauser, 2006). A second focus of work in our team has been on the investigation of expertise in complex domains. Early studies examined expertise in the domain of physics (Lay & Spada, 2000; Plötzner & Spada, 1993), a recent study examined expertise development in the domain of clinical psychology (Hauser, Spada, & Rummel, 2006). Thus, our research has been influenced by the CSCL literature as well as by research in cognitive science on expertise development. In the following paragraphs we will describe these two areas of research in more detail in order to derive hypotheses for the actual study.

Net-Based Interdisciplinary Collaboration

Our research has focused on the question of how to support and improve net-based interdisciplinary collaboration by means of instruction. In particular, we have chosen to investigate the *interdisciplinary collaboration of persons with medical and psychological background*, because collaboration is essential in this area. Secondly, we have focused on a *net-based collaboration setting*, because innovative computer-mediated settings open up new opportunities for collaboration across distance and time. This is important for the practicability of interdisciplinary collaborations and thus for the practical relevance of our research, as many times experts from different domains will not be co-located and face to face meetings are very time consuming. In the context of joint medical diagnosis, video conferencing systems have been advocated as a particularly suitable solution (Köhler & Trimpop, 2004).

In our prior studies (Rummel & Spada, 2005; Rummel et al., 2006) advanced medical students and advanced students of psychology collaborated on complex patient cases via a videoconferencing system. In two experiments we tested the influence of instructional measures on collaboration. Our experiments consisted of two phases: In a first phase, the learning phase, participants were instructed how to collaborate effectively by a script or they observed a model collaboration. In the second phase, the test phase, collaboration partners collaborated without further instruction. In this phase the learning effects of script or model were assessed by analyzing the collaborative process and its outcome, the joint solution. Observing a model collaboration proved to be a particularly effective method to instruct collaboration, and even more so if it was augmented by additional elaboration support (Rummel et al., 2006). Learning from scripted collaboration yielded mixed results: positive ones in the first study and not so good ones in the second study (Rummel et al., 2006). The main result of both our studies was that good collaboration can be instructed. Another product of this research was the development of a rating scheme that allows assessing the quality of collaborative processes (Meier, Spada, & Rummel, in press). Based on an iterative cycle of extensive literature search and detailed qualitative analyses of successful and unsuccessful dyads' collaboration, we developed a rating scheme that assesses the quality of collaboration processes reliably and in an efficient way. This rating scheme comprises nine dimensions (a more detailed description is provided below) and evaluates aspects of the communication, joint information processing, coordination, interpersonal relationship, and motivational aspects.

One limitation on this research is that the findings that have resulted from studies with advanced students could not simply be generalized to the collaboration among more experienced persons. However, it is particularly the experts of different domains who are required to collaborate in order to solve complex problems occurring in the real world.

Expertise Development

But what exactly is expertise? Research in cognitive science has investigated this question from the pioneering work of de Groot (1965) on chess expertise to research in manifold domains today (for an overview, see Ericsson, Charness, Feltovich, & Hoffmann, 2006). As a background for the present study, research on expertise development in the domains of medicine (e.g. Boshuizen, 2003, 2004; Boshuizen & Schmidt, 1992) and clinical psychology (Hauser et al., 2006) is particularly relevant:

Medical expertise has attracted much research attention since the 1970s, resulting in a large body of literature (e.g. Boshuizen & Schmidt, 1992; Boshuizen, 2003; 2004; Elstein, Shulman, & Sprafka, 1978). To examine expertise development in the domain of medicine, researchers have usually constructed a text-based case study and have asked physicians and novices to think aloud while working on it (e. g. Boshuizen & Schmidt, 1992). After diagnosing the case, participants were asked to elaborate on their assessment of the signs and symptoms (post-hoc pathophysiological explanations). With this approach, novices, intermediate and advanced students of medicine, and expert physicians with an average of four years of work experience have been compared. Regarding the quality of diagnoses, an increase up to the level of expert physicians was found (Boshuizen, 2004; Rikers, Schmidt, & Boshuizen, 2002). Earlier studies on expertise had revealed that the amount and structure of knowledge is one main factor that separates novices from experts (Feltovich et al., 2006), Boshuizen and colleagues also investigated the development of knowledge with growing domain expertise. They postulated three steps in the development of a medical expert: First, medical students acquire large amounts of declarative knowledge about biomedical processes. The representation of this knowledge can be understood as a loosely connected semantic network. With some clinical experience, declarative knowledge is then proceduralized in a process of "knowledge encapsulation". Encapsulated knowledge pertains to higher-order concepts under which lower-order concepts are subsumed. In routine work, experts verbalize only higher-order concepts. Researchers can detect knowledge encapsulations by comparing the experts' post-hoc explanations with think-aloud protocols. The phenomena of knowledge encapsulation led to lower scores for the experts in the number of recalled case statements (e.g. Boshuizen & Schmidt, 1992). However, if asked to do so, or when problems arose, experts were able to verbalize lower-order concepts. Thus, Boshuizen and colleagues found a linear increase in the amount of post-hoc pathophysiological explanations. In a final step, the clinical experience helps the medical expert to develop illness scripts for each disease. An illness script consists of enabling conditions (conditions and constraints of a disease), the fault (major malfunctions in bodily processes), and consequences (signs and symptoms). To summarize the results on expertise development in medicine: Boshuizen and colleagues found an increase in the amount of clinical and pathophysiological knowledge as well as in the quality of diagnoses (Boshuizen & Schmidt, 1992; Boshuizen, 2003, 2004; Rikers et al., 2002).

In one of our own studies (Hauser et al., 2006) we examined whether *expertise in clinical psychology* develops similar to expertise in medicine. We compared psychologists at five different training levels: novice, intermediate and advanced students, graduated trainee therapists (at least in the second year of their obligatory therapeutic on-the-job-training) and expert psychotherapists at least ten years after graduation. All participants had to complete an instrument consisting of three parts: (1) A knowledge test measuring basic psychological knowledge (e.g. classic conditioning), the application of the basics to clinical psychology (e.g. Mowrers 2-factor theory of avoidance learning), and knowledge in the area of clinical psychology (e.g. Becks cognitive triad). (2) A set of open-format questions that asked participants to write down as much as they know about one basic concept (schedules of reinforcement) and one clinical concept (schizophrenia). (3) The main part of the instrument consisted of two text-based patient cases (e.g. describing a patient with a social phobia). Similar to the studies by Boshuizen and colleagues (e.g. Rikers, et al., 2002) participants had to skim the case, recall important information in writing, diagnose the described patient, and finally explain the signs and symptoms. Three result patterns were found: On all variables measuring basic principles of psychology, the scores were highest in the first years of university studies, then knowledge decreased. On the variables measuring clinical knowledge, we found an increase up to the level of trainee therapists, then, at the expert level, knowledge decreased again. Pattern three was only found in the two diagnoses; the quality of diagnoses rose at the level of the intermediate students and then levelled off. Comparing these results to the studies on expertise in medicine, we can conclude that similar to novice students in medicine novice students in psychology first acquire declarative knowledge about basic principles of psychology. With practical experience, clinical psychological knowledge is acquired. Clinical psychological knowledge increased up to the level of trainee therapists, but in contrast to studies in medicine, decreased at the level of expert therapists. At the level of the trainee therapists we found some indications of knowledge encapsulation. At the expert level, more than ten years after graduation, basic psychological and theoretical clinical psychological knowledge had decreased and we did not find a clear indication of knowledge encapsulations. This did, however, not impair their diagnostic abilities: experts scored as high as advanced students and trainee therapists on the diagnoses. A further study is planned to examine the existence of illness scripts.

Individual problem solving as investigated in studies on expertise development is only one aspect of experts' work life. However, often experts are required to solve complex problems in collaboration with others. In these cases they do not only collaborate with other experts from their own domain, but often in an interdisciplinary context. Knowledge encapsulation and even more the loss of basic knowledge, but also the formation of illness scripts of experts may complicate the development of common ground (Clark & Brennan, 1991) and therefore interdisciplinary collaboration.

The present study aimed at overcoming the shortcomings of both the studies on computer-supported collaboration and the research on expertise development discussed above. In addition to our previous studies with students, we wanted to investigate net-based interdisciplinary collaboration across different levels of expertise. Thus, not only students at different stages of their education, but also job beginners and experienced professionals took part in this study. Also, building on studies of expertise development in individuals, we wanted to examine the collaboration of people with growing expertise and from different domains.

Hypotheses

The main goal of our study was to examine how growing domain experience influences collaborative process and outcome in an interdisciplinary, net-based setting. In our scenario a physician and a psychotherapist, or students from these disciplines, collaborated on solving a complex case study using a desktop videoconferencing system. Specifically, we investigated collaboration at three levels of expertise: student, trainee and expert. At all three levels dyads consisting of one partner from each of the two domains collaborated. At the *student level,* medical students who were at least in their third clinical semester (forth year of study) collaborated with students of psychology who had completed their specialization in clinical psychology (also in the forth year). At the *trainee level,* residents who had been working in a hospital for at least one year after graduation collaborated with trainee therapists who were at least in the second year of their on-the-job training after graduation. In Germany, medical doctors and psychologists have to complete postgraduate professional training in order to become a medical specialist or a psychotherapist. They are only allowed to establish an own practice after this training. And finally at the *expert-level,* physicians working as general practitioners collaborated with psychotherapists. All experts had worked in patient care for at least 10 years. It should be noted, however, that the expert psychotherapists, in contrast to the psychological trainee therapists, had not engaged in a certified postgraduate training at their time because this was not obligatory until 1998 in Germany. Collaborating partners did not know each other before taking part in the study. We carefully chose the degree of specialization of the two partners in order to model a collaborative scenario as authentic as possible. For example, one can easily think of a scenario where a patient consults his general practitioner because of a chronic disease, the general practitioner then notices that his patient also shows symptoms of a mental disease and consults with a psychotherapist. Most studies on expertise development in medicine were, however, conducted not with general practitioners but with even more specialized physicians, for example, cardiologists. Thus, predictions from this research could only be made with care. For the psychological participants, in contrast, our predictions were more straightforward because these were mainly the same participants who also took part in our study on expertise development in clinical psychology (Hauser et al., 2006).

We assumed that the growing domain expertise could have various positive but also negative effects on their collaboration: Hinds (1999) labeled the difficulties of experts to take the perspective of a layperson and design their communication accordingly "the curse of expertise". Interdisciplinary communication can be characterized as mutual expert-layperson communication (Bromme, Jucks, & Rambow, 2004; Rummel & Spada, 2005): each partner is expert in his own domain, but (at least relatively) novice in the other's domain. On the basis of this literature we can, for example, assume that experts will give highly abstract explanations that might not be understood by their partner from the other domain (Hinds, Patterson, & Pfeffer, 2001). Given the above research on expertise development, experts could also have forgotten some basic knowledge (Hauser et al., 2006) and thus could not be able to exchange as much information as students or trainees (or at least not as easily if knowledge encapsulation as described by Boshuizen and Schmidt, 1992, is the case). Moreover, experts could see less need to exchange domain specific information than participants with less experience, because they might implicitly feel the sole responsibility for their own domain part (Bromme & Nückles, 1998). Consequently, collaborating experts might arrive at a joint solution rather intuitively (Dreyfus & Dreyfus, 1986) not discussing their arguments with their partner. A precondition for discussion is awareness of the partner's knowledge and expertise. However, Bromme & Nückles, 1998, found that physicians seldom took notice of the difference between their own perspective of a patient and the perspective of nurses. In their study physicians were thus not likely to profit from the nurses' knowledge. In turn, novices might be more willing to take up alternative perspectives offered by a partner as they are less sure about their abilities to solve the case at hand. In the terminology of Heckhausen and Gollwitzer (1987), novices could be characterized as being in a motivational state of mind, whereas experts could be described as being in a volitional state of mind. In a motivational state of mind, people actively search for information and consider alternatives. They have not yet decided for a specific action and are trying to incorporate any relevant information in their decision making. In contrast, in a volitional state of mind, people focus on following through with an already made action plan. Thus, they lock themselves up to any new incoming information and centre their attention on the one alternative. Perhaps experts' interaction is in general less reciprocal than the interaction of persons with less experience because experts are used to adopting the leadership in their team. This could also affect dimensions like dialogue management (e.g., turn taking) and task management negatively.

Predictions for the *outcome* of the collaboration, the joint solution, were more difficult. Studies on expertise development in both domains have revealed that experts' diagnoses are as good as or better than those of advanced students. Consequently, we hypothesized that expert dyads, based on their large clinical experience, would score equally high or higher than less experienced dyads on the diagnoses. On the other hand, our case study was designed in such a way that a combination of medical and psychotherapeutic knowledge was required to come to a good solution. Therefore, not only the individual knowledge of the interacting partners, but also the quality of the collaboration during which the knowledge resources are combined plays an important role. If the partners do not pool their knowledge, they might fail to arrive at a good solution even if they would have the prerequisites. With regard to therapy planning: Research on expertise development in the medical domain has so far concentrated on measuring diagnostic skills and neglected the investigation of the development of therapeutic skills (Norman, Eva, Brooks, & Hamstra, 2006). In clinical psychology such research is also rare. In one of the few existing studies Caspar (1993) showed that during intake interviews inexperienced therapists verbalized more contents related to their own thinking. In contrast, experts information processing was more selective, automated, and complex. As they were less preoccupied with self-monitoring, experienced therapists had more cognitive resources available for the planning of therapy steps. Thus, we assumed that the more experienced participants would score as high as or even higher than less experienced dyads regarding the quality of their therapy plan.

Method

Sample and Design

Twenty-seven dyads (54 participants) took part in the study. Three expertise levels were implemented: student, trainee, and expert. Participants collaborated in dyads within their particular level of expertise. Dyads each consisted of one partner from the field of psychology and one from the field of medicine. Eleven advanced student dyads (*students*), ten intermediate dyads (*trainees*), and six expert dyads (*experts*) were composed (see Table 1).

Table 1: Sample and design of the study

Student Level: *Advanced medical students collaborating with advanced students of psychology*	*Trainee Level:* *Physicians in their residency collaborating with postgraduate trainee therapists*	*Expert Level:* *General practitioners collaborating with psychotherapists, (both at least ten years after graduation)*
n (dyads) = 11	*n* (dyads) = 10	*n* (dyads) = 6

Procedure

After an initial introduction, the two partners of each dyad were seated in different rooms and received training with the computer-mediated setting. In this training, all technical skills needed to complete the tasks were taught. Participants learned to work with the desktop videoconference system, and with the shared and individual editors. After the technical training they received a text-based case study (752 words) describing a woman suffering from physiological and psychological symptoms, and some domain-specific physiological and psychological literature. Participants were given 15 minutes to read the case study and to skim the text material. During this individual preparation phase they were not allowed to speak to each other. Next, participants collaborated on a threefold task: (1) They were asked to diagnose the case (multiple sclerosis and major depression), (2) state differential diagnoses (for example borreliosis, adjustment disorder), and (3) plan medical and psychological therapy steps for the main diagnoses. The time to complete these tasks was limited to 60 minutes. During the collaboration phase, participants communicated via a desktop videoconference system with the audio-video connection, individual text editors to take notes, and a shared text editor to compile the joint solution. Finally, each participant individually filled out a post-test measuring knowledge about important aspects of collaborating well in an interdisciplinary, net-based setting, and a questionnaire asking for the perceived helpfulness of such collaboration.

Dependent Variables

Dependent variables on the collaborative process and on the joint solution were assessed. To analyze the quality of *collaborative process* we applied a rating scheme that allows assessing collaboration quality by comparing a dyad’s interaction with a pre-defined standard (Meier et al., in press). The rating scheme had been developed in two previous studies that had tested the effects of instructional measures on a subsequent unsupported collaboration (Rummel & Spada, 2005; Rummel et al., 2006). Based on qualitative analyses of transcribed collaboration dialogue from the first study, and theoretical concepts from the relevant literature, nine dimensions of successful collaboration had been defined. Then, the rating scheme had been applied to data from the second study, where it had helped detecting effects of instruction on the subsequent collaboration and had proven to be a valid and reliable assessment method (Meier et al., in press). The rating scheme comprises the following nine dimensions: (1) *Sustaining mutual understanding* measures the extent to which participants express themselves intelligibly, e.g. whether they explain technical terms when using them or whether they tailor their contributions to the knowledge of their partner. (2) *Dialogue management* assesses turn taking and other aspects of communicative process coordination. (3) *Information Pooling* denotes the extent to which the partners take responsibility for their own domain, whether they see the partner as resource to gather information from the other domain, and the extent to which information from both domains is referenced in the solution. (4) *Reaching consensus* evaluates the decision making process, for instance, whether the partners critically discuss and mutually evaluate their arguments before coming to a decision. (5) *Task division* measures the extent to which the participants plan their solution process and divide the task in meaningful subtasks that are solved individually or in collaboration. (6) *Time management* assesses how participants deal with the time available for solving the task. (7) *Technical coordination* assesses whether technical resources such as the individual editors and the shared editor are used effectively and how participants deal with technical problems arising. (8) *Reciprocal interaction* examines whether the interaction is symmetrical, respectful, and whether both partners can contribute to their joint solution in equal shares. (9) *Individual task orientation* (psych. or med.) is a dimension relating to motivational aspects in the behaviour of the partners. Task orientation is the commitment of each partner to work towards solving the task, his or her willingness to put effort in the collaboration, and the extent to which volitional strategies are used. In contrast to all other dimensions, we assessed this dimension on the level of the individual rather than the dyad. Thus, effectively ten variables resulted from the process ratings. Each variable was rated on a five-point rating scale ranging from 0 (very bad) to 4 (very good). The ratings were made as the rater watched the videotaped collaboration of a dyad. In order to reduce cognitive load on the raters, each dyad's videotape was segmented into three parts. The three parts were consecutively rated on the ten variables of the rating scheme. Finally the three ratings for each variable were aggregated. These aggregated values are reported in the results section below. In addition to applying the rating scheme to assess the quality of the collaborative process, we gathered process data from logfiles. Our earlier studies have revealed that working *also* individually is essential for the quality of collaborative solutions because participants need this individual time to reflect their joint considerations on the background of their own domain knowledge (Hermann et al., 2001; Rummel & Spada, 2005). But, individual work is often neglected in computer-mediated collaboration (Hermann et al., 2001). Thus, we measured the amount of individual or joint work, and the number and length of work phases from the logfiles. To asses the quality of the *joint solution*, the solutions of all dyads were blind rated by a medical and a psychotherapeutic expert. Each expert rated the quality of the diagnoses, differential diagnoses and therapy steps for her domain (medicine and clinical psychology) on a six-point scale (1 = very bad to 6 = very good).

Results and Discussion

Collaborative Process

We had hypothesized that experts would score lower than advanced students and trainees with regard to particular aspects of the collaborative process. In terms of the dimensions of the rating scheme the following variables could be affected: dialogue management, information pooling, reaching consensus, reciprocal interaction, task division. Table 2 gives an overview of the means and standard deviations of the *ratings of the collaborative processes*. A multivariate analysis of variance (MANOVA) of the ten process variables revealed a marginally significant overall effect for the expertise level (F (2, 24) = 1.9, p = .05, η^2 = .62). Subsequent ANOVAs showed that the trainee dyads scored best followed by the students and the experts formed the taillight. Altogether, eight out of ten dimensions showed this pattern. Consistent with our assumptions we found substantial group differences on the following dimensions: *information pooling* (F (2, 24) = 3.34, p = 0.05, η^2 = 0.22), *technical coordination* (F (2, 24) = 6.39, p = 0.01, η^2 = 0.35), and *reciprocal interaction* (F (2, 24) = 4.46, p = 0.02, η^2 = 0.27). Figure 1 illustrates this pattern by showing the means for the dimension *reciprocal interaction*. On five other variables the same pattern was found (*sustaining mutual understanding, dialogue management, reaching consensus, task division, task orientation psychological participant*), however, the group differences did not reach the significance level. Other patterns were found only for the variables *time management* and *task orientation medical participants*. However, the differences were small and did not reach the significance level.

Table 2: Means and standard deviations (in parentheses) for the ratings of collaboration quality.[+]

	Students	*Trainees*	*Experts*
Sustaining mutual understanding	2.88 (0.73)	2.93 (0.78)	2.72 (0.90)
Dialogue management	2.58 (1.03)	2.97 (0.90)	1.94 (0.93)
Information Pooling*	2.42 (0.79)	3.17 (0.79)	2.22 (0.86)
Reaching Consensus	2.58 (0.92)	2.78 (1.26)	2.17 (0.69)
Task Division	2.02 (1.01)	2.60 (1.07)	1.33 (0.60)
Time Management	0.88(1.11)	0.63 (0.60)	0.94 (0.71)
Technical Coordination*	2.79 (0.83)	3.18 (0.85)	1.64 (0.87)
Reciprocal Interaction*	2.64 (1.18)	3.27 (0.56)	1.83 (0.91)
Individual task orientation (med.)	3.33 (0.49)	2.87 (0.89)	2.83 (1.01)
Individual task orientation (psych.)	2.85 (0.58)	3.10 (0.97)	2.56 (0.62)

[+]Scores range from 0 = very bad to 4 = very good, *$p \leq .05$

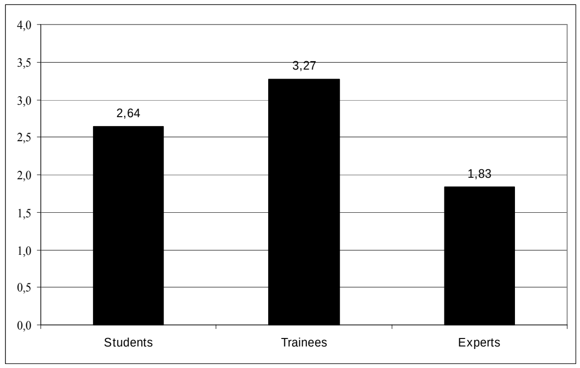

Figure 1: Results for the process dimension reciprocal interaction

Table 3 shows the results of the *logfile analysis*. Overall, participants spent more than twice as much time on collaborative work than on individual work. The time spent working individually decreased with growing expertise. Given the small sample and the relatively high variances within the expertise levels, the group differences did, however, not reach the significance level (amount of collaborative work: F (2, 24) = 1.41, p = 0.26, η^2 = 0.11; individual work: F (2, 24) = 1.57, p = .23, η^2 = 0.12). As former studies (Hermann et al., 2001; Rummel & Spada, 2005) have revealed, individual work is positively related to the joint outcome. In accordance with these findings, the average correlation of the amount of individual work with the variables of the quality of the joint solution (see Table 4) was r = .30. Concerning the number of phases, the expertise levels differed significantly (F (2, 24) = 5.26, p = .01, η^2 = .30). Students alternated more often between joint and individual work than trainees and experts. For this variable, the average correlation with the outcome variables was r = .26.

Table 3: Means and standard deviations (in parentheses) for the logfile data

	Students	*Trainees*	*Experts*
Collaborative Time (minutes)	41.91 (9.67)	47.10 (8.13)	49.00 (10.16)
Individual Time (minutes)	17.45 (9.65)	12.90 (8.13)	9.83 (8.52)
Number of Phases*	10.82 (4.45)	7.10 (2.56)	5.83 (1.94)

$p \leq .05$

Joint Solutions

The ratings of the joint solutions are shown in Table 4. The medical ratings were given by a medical expert, the psychological ratings by a psychotherapeutic expert. On the medical ratings no significant differences were found between expertise levels; neither for the diagnoses, nor for the differential diagnoses, nor for the planned therapy steps. Multiple sclerosis is a rather uncommon diagnose for general practitioners. Perhaps we asked too much of them when presenting them with this complex disease. On the psychological ratings a significant difference between expertise levels was found regarding the differential diagnoses The trainee dyads scored best, followed by the student dyads and, finally the expert dyads (F (2, 24) = 4.63, p = .02, η^2 = 0.28). Although not significant (F (2, 24) = 1.78, p = 0.19, η^2 = 0.13), the same descriptive pattern could be found in the diagnoses. This result contradicts assumptions we had derived from experts' performance in diagnosing in the Hauser at al. (2006) study. Contrary to the present study, expert psychotherapists had scored as high as less experienced psychologists on the diagnoses.

Table 4: Means and standard deviations (in Parentheses) for the expert ratings of the joint solutions.[+]

	Students	*Trainees*	*Experts*
Medical Ratings			
Diagnoses	4.00 (1.84)	3.40 (1.51)	3.50 (1.38)
Differential Diagnoses	4.18 (0.87)	4.50 (0.71)	3.67 (0.82)
Therapy Steps	3.82 (1.60)	3.10 (1.29)	2.33 (1.21)
Psychological Ratings			
Diagnoses	4.55 (1.37)	4.90 (0.99)	3.67 (1.51)
Differential Diagnoses*	2.73 (1.42)	3.70 (1.16)	1.83 (0.75)
Therapy Steps	4.73 (1.01)	4.60 (1.17)	5.00 (1.67)

[+]Scores range from 1 = very bad to 6 = very good, *$p \leq .05$

General Discussion and Outlook

The main goal of the present study was to examine how growing domain expertise influences net-based interdisciplinary collaboration of persons with medical and psychological background. Consequently, process and outcome of collaborations at different expertise levels were compared. Advanced students of medicine and clinical psychology collaborated with each other, physicians in their residency collaborated with postgraduate trainee therapists, and experienced general practitioners collaborated with experienced psychotherapists. In our collaborative setting participants did not meet in person but collaborated via a videoconferencing system with individual text editors and a shared one. Their joint task was to diagnose a complex case study, state differential diagnoses, and plan therapy steps. As the patient showed symptoms of a medical disease (multiple sclerosis) as well as a mental disease (major depression), the task could only be solved with interdisciplinary effort. The collaborations of all 27 dyads were video-recorded. To assess the quality of the collaborative processes a rating scheme developed by Meier et al. (in press) was applied. This rating scheme consisted of the nine dimensions: sustaining mutual understanding, dialogue management, information pooling, reaching consensus, task division, time management, technical coordination, reciprocal interaction, and individual task orientation. In addition to the process ratings, log files were analyzed for individual and joint time, and the number of work phases. Also, the joint solutions of the case were analyzed.

As we had hypothesized, expert dyads scored lowest on most variables of the *collaborative process ratings*. We also found that trainee dyads outperformed student dyads on most of these variables. Particularly clear results were found for information pooling, reciprocal interaction, and technical coordination. For the variables mutual understanding, dialogue management, task coordination, and individual task orientation the same pattern resulted, but the differences did not yield statistical significance. Analyses of *process logfiles* revealed that experts spent more time working collaboratively and less time working individually than trainees and students, although this result did not become statistically significant. Also they alternated less frequently between the two modes. As had been found in former studies (Hermann et al., 2001; Rummel & Spada, 2005), the amount of individual work was positively correlated with the quality of the joint outcome. Also, a higher number of work phases correlated positively with a better solution. We can conclude that a more balanced collaboration, with a greater proportion of individual work and a more frequent alternation between modes of interaction, could have improved the outcome of the more experienced dyads. In interpreting the results let us go back to the studies on expertise development in medicine and clinical psychology cited in the introduction (e.g. Boshuizen, 2004; Hauser et al., 2006). Based on the findings regarding knowledge encapsulations, decrease in theoretical knowledge, and the formation of illness scripts, we assumed that large practical experience would affect the exchange of information on the case. Together with potentially arising social processes such experts taking over leadership and responsibility for the own domain, this might explain the findings on the collaborative process in the present study. However, the situation is not as negative at it may seem. In the present study we only looked at unsupported collaboration. From our earlier studies (Rummel & Spada, 2005; Rummel et al., 2006) we know effective methods for enhancing collaboration that could be tailored to support particularly collaborating experts.

The results on the solution quality were mixed. In the *medical ratings*, contrary to our assumptions, no significant differences could be found. However, as was noted, the medical disease described in the patient case (multiple sclerosis) is a rather uncommon disease for general practitioners. One could imagine that when confronted with such a complex symptom pattern in their daily work they would consult with a more specialized physician for further steps. However, at least in Germany general practitioners usually are the first physician patients consult and thus these physicians should be able to cope with complex and rare diseases at least in the beginning. Then, the results for the planning of therapy steps might be explained by the fact that multiple sclerosis is an uncommon disease, but not experts' low performance on the diagnoses and differential diagnoses. On these variables they should have scored higher than student dyads and trainee dyads as diagnosing is an important competence for general practitioners in order to find the right specialist to consult. As an additional explanation of the results, consider that in most studies on expertise in medicine experts were less experienced than the expert physicians examined in our study. In the study of Boshuizen and Schmidt (1992) experts had worked four years after graduation on average, while in our physicians had worked at least ten years after graduation. Perhaps, the longer time span after graduation also causes experts from the medical domain to forget theoretical clinical knowledge as it was found in our study on clinical psychology (Hauser et al., 2006). In general, therapy planning has been neglected in the existing research on expertise in medicine (Norman et al., 2006) and should be focused on in future studies.

The results on the *psychological ratings* of the joint solutions were surprising. Contrary to our study in expertise development, the experts formed the taillight regarding psychological diagnoses, and differential diagnoses. We had assumed that experts would be able to compensate for potential difficulties in their communication through their high experience with patient cases. But this hypothesis was not supported by our results. Also in the planning of therapy steps, contrary to our assumptions no substantial differences between the levels could be found. In interpreting these results we would like to emphasize once more that the expert psychotherapists participating in the present study have not undergone a postgraduate professional training comparable to the one trainee therapists engage in today, because this was not obligatory until 1998 in Germany. In other words, the above results might in part be due to our cross sectional design, i.e. an effect of differences among cohorts.

In explaining the results on the quality of the joint solution at large let us consider a thought we already brought up in the introduction. Our case study was designed in such a way that combining medical and psychotherapeutic knowledge was required to come to a good solution. Therefore, not only the individual knowledge and abilities of the interacting partners, but also the quality of their collaboration, during which knowledge resources were to be combined, played an important role. If the partners failed to pool their knowledge, they could have arrived at poor solution even if they had had the prerequisites to do better.

To sum up, our study showed that growing domain expertise can have negative effects on the net-based collaboration among persons from different, yet related domains. For the outcome (the joint solution) the results were mixed. As the outcome was influenced not only by the individual expertise of the collaborating partners, but also by the quality of their collaboration, providing support for the collaborative process could lead to better collaborative solutions. Further studies should work towards developing collaboration support tailored to the specific problems encountered at the expert level.

In concluding, we would like to emphasize that in contrast to previous case studies on interdisciplinary collaboration, with the present study we attempted to systematically test hypotheses derived from research on expertise development and computer-supported collaboration. Although net-based interdisciplinary collaboration is a very complex area of research with many interwoven aspects, we are confident that further systematic empirical research following this idea will yield more insights in this interesting and relevant field.

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Acknowledgements

The present research was supported by the Deutsche Forschungsgemeinschaft (DFG; [German Science Foundation]) with project grants to Hans Spada and Franz Caspar (Sp 251/16-2 and 16-3). We thank our student research assistants Christine Kalweit, Ann-Kristin Reinhold, and Britta Stumpf for their help in data collection and analysis. Furthermore, we would like to acknowledge Katrin Wenning and Katrin Manner, our psychological and medical experts for their help in material development and ratings of joint solutions. Moreover, we would like to thank Anne Meier, who has made a substantial contribution to this project: the rating scheme for the collaborative process analysis was largely developed as part of her thesis work.

Partner Modeling Is Mutual

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Abstract. It has been hypothesized that collaborative learning is related to the cognitive effort made by co-learners to build a shared understanding. The process of constructing this shared understanding requires that each team member builds some kind of representation of the behavior, beliefs, knowledge or intentions of other group members. In two empirical studies, we measured the accuracy of the mutual model, i.e. the difference between what A believes B knows, has done or intends to do and what B actually knows, has done or intends to do. In both studies, we found a significant correlation between the accuracy of A's model of B and the accuracy of B's model of A. This leads us to think that the process of modeling one's partners does not simply reflect individual attitudes or skills but emerges as a property of group interactions. We describe on-going studies that explore these preliminary results.

Introduction

It is now broadly admitted that learners do not benefit from collaboration simply because they are in a group but because collaboration triggers additional activities such as explanation, disagreement and mutual regulation (Dillenbourg, 1999). According to Roschelle and Teasley (1995), many CSCL scholars conceptualized collaborative learning as an activity in which shared knowledge is constructed by peers through their interactions with each other and also with their environment. The notion of shared knowledge is derived from psycholinguistic concept of “grounding” (Clark &Wilkes-Gibbs, 1986): during interactions, the “interactants” constantly try to ensure a good mutual understanding. Grounding is the collective process through which individuals engaged in a conversation try to ensure their mutual understanding. 'Shared understanding' or 'mutual understanding' is a very intuitive concept, both for analyzing interactions and for designing applications, which probably explains their impact on CSCL. However, the notion of shared understanding is questioned both within psycholinguistics (Sperber & Wilson, 1986) and within CSCL (Baker, Hansen, Joiner & Traum, 1999; Koschmann & LeBaron 2003). Our research questioned mutual understanding in a different way: we zoom in on the mechanics of grounding by analyzing how a shared solution emerges from the sum of a long sequence of contributions (Dillenbourg & Traum, 2006). We further attempt to understand the socio-cognitive benefits of co-constructing a shared understanding. We investigate a mechanism that is hypothesized to lie at the heart of grounding. For Clark and Brennan (1991), common grounds are a set of *mutual beliefs* defined as the amount of information shared (e.g. presuppositions, knowledge, assumptions, beliefs). Establishing this set of beliefs requires that the co-learners build some representation of their partners’ knowledge, beliefs and goals. We refer to the process of building assumptions about the beliefs and the knowledge of their partner(s) as **mutual modeling** (Dillenbourg, 1999). However, the abstract and unobservable aspect of this process raises methodological challenges regarding its comprehension by researchers. Therefore, this paper attempts to ask a general question about the socio-cognitive nature of mutual modeling by assessing whether the process of modeling one's partner is grounded at the individual or the group level.

The paper does not describe environments for collaborative learning but reports basic research on the socio-cognitive mechanisms related to mutual modeling. The first section explores the concept of mutual modeling and its relationship with CSCL features such as scripts and awareness tools. The second and third sections describe two empirical studies in which the accuracy of mutual models is measured. The concluding section describes how the hypotheses arising from these two studies are currently being investigated through two other studies, which focus on a CSCL setting with a stronger educational flavor.

Mutual modeling in collaborative tasks

The ability to perceive a partner's understanding and to adapt to his/her viewpoint has been investigated under the labels of intersubjectivity (Wertsch, 1985; Bromme, 2000) and audience design (Lockridge & Brennan, 2002). Suthers (2006) recently proposed “the technology affordances of intersubjective meaning-making” as an integrative agenda for CSCL research. For him, a common denominator of understanding learning in a collaborative setting is the peers' attempt to make sense of situations and of each other. Intersubjectivity is *played* in the field of the physical and historical context available to the participants to *jointly compose interpretations*, which could be considered as a new gist for collaborative learning, an alternative to the notion of producing mutual-beliefs about making unshared information shared. To sum up, taking into account the peer's perspective is a crux facet of intersubjectivity on which most of the social activities depend. As highlighted by Malle (2003), the ability to represent and reason about self and other's mental states (e.g. beliefs, desires, intentions, mere thoughts, experiences, emotions, attitudes) is a great achievement in the evolution of the human mind and is considered a prerequisite for many social and cognitive processes such as natural language acquisition, social interaction, reflexive thought, and moral development.

The term "mutual modeling" does not imply that collaborators maintain a detailed representation of their partner's knowledge, nor an explicit one. Simply stated, if A is able to (dis-)agree with B, it means that A needs has representation of B's intentions; if A wants to repair B's misunderstanding, A needs some representation of what B has understood. Mutual modeling is as functional as the grounding process: the degree of accuracy depends on the task requirements; an extremely high level of accuracy is demanded if two pilots collaborate on landing a plane, as in Hutchins' (1995) observations, but the level of accuracy can be much lower if the pilots are discussing their last party. Moreover, mutual modeling does not occur in a vacuum but is based on multiple inference mechanisms. Common grounds are initialized by the assumptions people make about their partner from cues such as his/her community membership (age, culture, profession, ...) and from co-presence (e.g. common ground includes any event to which A and B attended together) (Clark & Marshall, 1981). Several scholars studied how this initial modeling impacts communication, namely because it can easily be manipulated. For instance, Slugoski, Lalljee, Lamb & Ginsburg (1993) pretended to their research subjects that their (fake) partner had or had not received the same information. They observed that the subjects adapted to their partner by focusing the explanation on the items that (s)he was supposed to ignore. Brennan (1991) showed that the subjects used different initial strategies in forming queries depending on who they were told their partner was. Other simpler inference mechanisms such as default reasoning rules (e.g. B agrees with me unless he disagrees) are developed according to the conversational context. Mutual modeling could not occur independently from culturally acquired interaction schemata that constrain the space of interpretation of the other's behavior. Actually, the CSCL notion of 'scripts' (Dillenbourg, 2002) can be conceptualized as providing co-learners with an explicit schema that narrows down the space of interpretations and therefore serves as prosthesis for mutual modeling. Another prosthesis for mutual modeling is the notion of awareness tools (Greenberg & Roseman, 1996); these are features of CSCW environments in which A is informed about the actions of B that A has not directly perceived.

Even when mutual modeling is not detailed and explicit, reasoning about what one's partner believes involves some cognitive load. For Clark & Wilkes-Gibbs (1986), what is important is not the individual effort made by the receiver of a communicative act, but the overall least collaborative effort. The cost of producing a perfect utterance may be higher than the cost of repairing the potential problems which may arise through misunderstandings. For instance, subjects are less careful about adapting utterances to their partner when they know they can provide feedback on his/her understanding (Schober, 1993). We introduce instead the notion of 'optimal collaborative effort' (Dillenbourg et al, 1996) to stress that misunderstanding should not be viewed as something to be avoided (even if this were possible), but as an opportunity to explain, to justify, and so forth. Here we enter the global argument regarding cognitive load in learning activities, namely in discovery learning environments: there is no learning without cognitive load, but overload may hinder learning (Paas, Renkl & Sweller, 2003). In the context of collaborative learning, we understand the cognitive load induced by mutual modeling as part of Schwartz's (1995) notion of effort towards a shared understanding. For instance, conflict-resolution scripts or JIGSAW scripts are purposely designed for augmenting (reasonably) the effort group members have to engage to reach a shared solution.

Mutual modeling has many dimensions, from which we dissociated 'dispositional' versus 'situational' aspects. The 'dispositional' aspects refer to A's representation of B's long term knowledge, skills or traits. It is thus closely related to the notion of transactive memory (Wegner, 1987; Moreland, 2000). 'Situational' aspects refer to A's representation of B's knowledge, behavior or intention specifically activated in the situation in which A and B are collaborating.

This leads us to the long term research question that underlies our work: does the mutual modeling process contribute to the learning outcomes of collaborative problem solving? This question is difficult to investigate because the degree of mutual modeling is both difficult to manipulate as an independent variable, and difficult to measure as a dependent variable. Measuring it is difficult because, as soon as one asks learners what their partner knows, is doing or intends to do, we trigger a modeling process beyond what it would 'naturally' be. Controlling the degree of mutual modeling is also difficult. As we mentioned earlier, scripts and awareness tools potentially influence the mutual modeling process, acting as a kind of prosthesis. Now, like any prosthesis involved in learning, we ignore whether scripts and awareness tools will augment the mutual modeling process (by scaffolding it) or inhibit it (by making it useless). Moreover, it is difficult to estimate the accuracy of a mutual model in absolute terms. Thus, this study focuses on a simple question: considering M(A,B) as being A's representation of B, **what is the relationship between M(A,B) and M(B,A)?**

An alternative hypothesis is that participants do not build a representation of their partners' mental states but instead build a representation of the interaction process at the group level: instead of modeling who knows what, who does what or who said what, the team members could maintain a representation of what the team knows, has done or has said. We refer to this as the group model. This alternative is directly inspired by distributed cognition theories (Pea, 1993; Salomon, 1993; Hutchins 1995) and the team mental model (Canon-Bowers, Salas, Converse, 1993). The two hypotheses are of course complementary since these two models feed each other.

This paper does not directly examine these general research questions but reports results collected in two empirical studies on mutual modeling, one occurring in a virtual environment and the second in real space. These results are discussed in light of social and cognitive theories. The discussion also mentions on-going studies on the mutual modeling process within more traditional collaborative learning settings.

Study 1

We attempted to measure mutual modeling by using awareness tools in a collaborative video game called Spaceminers. The research question was to study the impact of an awareness tool on group performance and mutual modeling. The availability of an awareness tool was our independent variable. The main results have been published in (Nova, Wehrle, Goslin, Bourquin, Dillenbourg, 2006). We focus here on the question addressed in the introduction, that is, the relation between the modeling performed by each user or the relation between M (A,B) and M (B,A). Our main dependent variable is the mutual modeling accuracy, henceforth referred to as MM-accuracy

Experiment design

SpaceMiners is a 3D computer game that involves two players in space missions in which they have to collect minerals located in asteroids and bring them to a space station. To do so, they shoot drones through the space after choosing their initial direction and speed. Once launched, the trajectory of drones is only influenced by the gravity of planets and by specific tools that players collaboratively position between planets.

During the experiment, the teams were confronted with three increasingly complex situations. The experiment was 2 hours long, with a 30 minutes tutorial and 3 levels of 30 minutes. Thirty-six persons participated in this study, all native French speakers. We constituted 18 pairs of participants (N = 18) who were not familiar with each other. The pairs were assigned randomly to either the control condition (without the awareness tool) or the awareness condition (with the awareness tool). In the awareness condition, team members could view what their partner was looking at and were therefore expected to more accurately infer his/her teammate's intentions. Each player sat in front of a distinct computer located in different rooms. They interacted with the game using a regular Logitech joystick and communicated with each other through an audio channel.

Measures

Task performance was measured by the score reached by the subjects after three situations. In order to evaluate the mutual modeling accuracy during the task, we used two questionnaires as shown on Figure 1. Both of them were displayed during each of the three phases of the game, as a transparent layer appearing on the game level. The first questionnaire concerned the player’s intended actions. It asked each player about what they were intending to do at the moment (guide his partner, try to understand his strategy, try to establish a common strategy, adjusting a shot, etc.). The second questionnaire asked each player about what he thought the partner was intending to do. Some answers were identical in both questionnaires (like “adjusting a shot”) while others were reversed. For instance, the answer "guide him" was reversed as "guide me" and vice-versa. Each questionnaire then had 10 questions that covered the basic actions that could be performed.

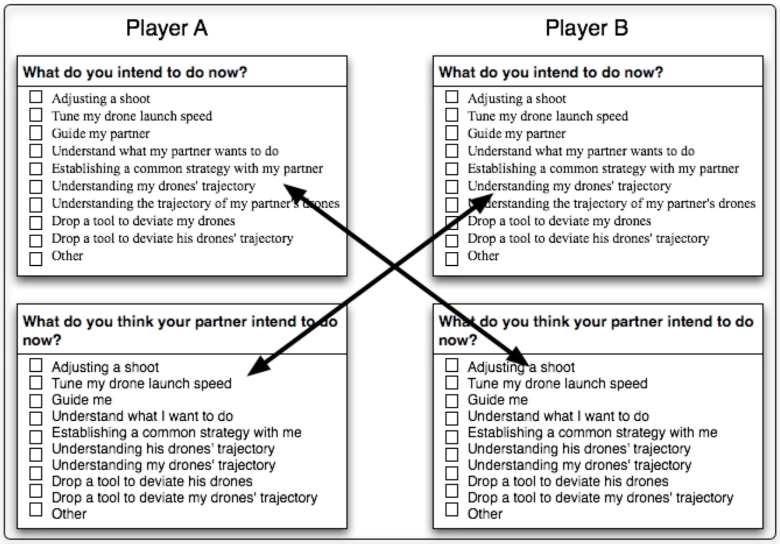

Figure 1: Crossed questions for measuring mutual modeling accuracy.

These questionnaires gave us the possibility of comparing player A's prediction about B's intentions with B's self-declared intentions. Of course, this method presents the same limitations of any questionnaire in which somebody has to self-declare his or her intentions. We compared the first answer of a player (about what A is intending to do) to the answer of his partner to the second question (about what B believes A is doing). Our estimation of MM -accuracy has been computed as the number of common answers given by the two players to those two questionnaires: does A's prediction of B's answer matches B's actual answer? Since there were 3 evaluations (one per level), we computed the MM-accuracy per individual for each level of the game. The global MM-accuracy is the sum of these 3.

Findings and Discussion

The awareness tool permitted higher group performance, but it did not improve the accuracy of the mutual model. However, within the experimental group, the pairs who intensively used the awareness tools obtained a significantly higher MM accuracy (for more details, see Nova et al., 2006). In order to compare M (A,B) and M (B,A), we computed intraclass correlation as described by Kenny et al. (1998) from the answers to the cross-questionnaires. We found a positive and significant correlation ($r = .38$, $p < .05$) between M (A,B) and M (B.A). This sounds like a minor result for this particular study but actually conveys an important outcome: mutual modeling appears to be a group variable rather than a personal activity. We expected MM-accuracy to be a personal parameter, i.e. that some participants spontaneously pay more attention or engage more effort in monitoring their peer. This could be due to some social attitude or to specific cognitive skills required to build a mutual model. This strong correlation between M (A,B) and M (B.A) supports a different hypothesis in which mutual modeling emerges as a property of the quality of interactions among peers: some pairs seems to collaborate in such a way that their verbal and non-verbal interactions produce more cues available to both partners so that they can build a mutual model. This does not remove individual variability (correlation was not 1). Interestingly, we found that the relation between M(A,B) and M(B,A) was not very different in the two conditions: the average absolute difference between MM-Accuracy (A,B) and MM-accuracy (B,A) is not significantly different with or without the awareness tool ($F[1,13]= 0.1445$, p-value = 0.7097)

Study 2

In this second study, instead of evaluating mutual modeling during the task, we chose to measure it after task completion. This experiment was based on a pervasive game called Catchbob. As in the previous experiment, this game was used to evaluate the influence of awareness tools on group performance and MM-accuracy, but we will focus here on the results concerning the relationship between M(A,B) and M (B,A).

Experimental design

Catchbob is an experimental platform implemented as a mobile game in which groups of 3 players have to solve a joint task. The game was played on the school campus and participants had to find a virtual object ('Bob') and catch it by forming a triangle around it. Players used a Tablet PC that displays a map of the campus and an indication of their personal distance from Bob. Their annotations on the map were shared with the two other players, but fadeout after a few minutes. The awareness tool displayed the location of the two other players on the map. Henceforth, we will refer to this information as mutual location awareness (MLA). It constituted our independent variable.

In this study, we selected groups of students from the same class and who therefore knew each other. Ninety students participated in this experiment. We assigned 10 groups of 3 persons to each of our three experimental conditions: the control condition (without MLA) and two experimental conditions: synchronous MLA (display current position of each player) and asynchronous MLA (display current position of each player and their spatial trace). We controlled group gender so that each condition was made up of 25% of female and 75% of male.

Measures

As a dependent variable, we measured MM-accuracy by asking players to draw their own path and the one of each of their partners after the game. This enabled us to calculate the number of errors players made while drawing the path of their partners. We compared the path player A attributed to B with B's real paths recorded by the system and the same for A&C or B&C as depicted on Figure 2.

Figure 2. (Left) Drawing A made of B's path; (Right) Real path followed by B as extracted from the logfile.

We computed the number of errors between M(A, B) and M(system, B). What we counted as an error was either drawing a place where the partner had not been or not drawing a place where he/she had gone. Three criteria were defined to describe these errors: distance (if the line was longer than the maximum size of our campus corridor), presence of an obstacle (door/wall/glass), and walking back (not perceived as an error). An individual MM-accuracy is the sum of errors made by a player about his/her two partners' paths. We calculated MM-accuracy for each individual (M (A,B), M (B,A), M (A, C), M (B,C),…) and for each group (the sum of the individual measures). It is important to stress that subjects made very few mistakes when drawing their own path on the campus (85% made 0 errors). This enables us to consider mistakes in their partners' path as being due to a lack of mutual modeling accuracy instead of being due to spatial skills (e.g. a difficulty in reporting trajectories on a map).

Findings and Discussion

We did not find any significant difference regarding the task performance between the three experimental conditions. However, our surprise was that the absence of the awareness tool led player to higher MM-accuracy: players better remembered their partners' path if they did not see their position permanently. We will not enter into the details of these results but simply stress that teams without MLA made more annotations on the map. It seems that permanent MLA has an underwhelming effect (Nova et al., 2005). Let us now focus on the relationship between

M (A,B) and M (B,A). We checked the intra-group dependence of the results through the computation of intra-class correlation: the correlation is again positive ($r = .41$) and significant ($p = .01$). The number of errors made by the subjects is correlated with the number of errors made by the other partners. This result confirms the correlation found in the first study. This second result is even more surprising for us than the former: despite the high heterogeneity of spatial representation skills among adults (see for instance Liben et al, 1981), this high correlation indicates again that MM-accuracy reflects more group processes than personal features. Since team members did not interact massively during the task, the intra-group correlation may not be explained by the quality of verbal interactions but by other aspects of their collaboration, probably the quality of the task strategy that emerged in the group. However, the relation between strategy and MM-accuracy is complex: if we do a post-hoc split, groups with a high level of MM-accuracy do not perform better than pairs with low MM-accuracy ($F[1,17] = 1.4456$, $p = 0.2452$).

Discussion and further studies

The results of these two studies revealed a correlation between the model peers built about each others' behaviors and intentions. Simply stated, if team member A builds an accurate model of nember B, then B also tends to build an accurate model of A. The conclusion we draw at this point is that the activity of modeling the partner is not reciprocal but mutual. A reciprocal relationship means that modeling is an individual activity where A infers M (A,B) from B's actions and utterances. A mutual relationship implies that M(A,B) and M(B,A) are jointly constructed through interactions. The term 'mutual' may mean not only that A builds M(A,B), but he also builds M(A, M (B,A)). We will not enter in the long debate on an infinite regress of nested models (discussed in Smith, 1982 or in Clark, 1996). Another interpretation is that team members actually build a model of the group-in-interaction, something like M (A, AB). We are not able to choose among different hypotheses at this stage.

These findings are not very robust because they emerged as side-effects of other research questions, but, nonetheless convincing since the same correlation has been observed in two different contexts: virtual space in study 1 versus real space in study 2; groups of 2 in study 1 versus groups of 3 in study 2. Moreover, these results have been found using different methods: on-task in study 1 versus off-task in study 2, subjective validation (comparing A's model to B's answer) in study 1 versus objective validation in study 2 (comparing A's model with B's behavior). This diversity somewhat consolidates our results but these results are still preliminary: the selected tasks were not proper learning tasks and, overall, we still face serious methodological difficulties. On the one hand, asking learners 'on task' what their partner knows, is doing or intends to do triggers a modeling process which could alter the natural modeling process. On the other hand, providing learners with an 'after-task' survey implies mnemonic and rationalization biases. In other words, the nature of mutual modeling implies methodological challenges that call for indirect measures and assessment methods. Furthermore, mutual modeling in everyday life involves a large variety of mental states to be represented such as knowledge, behaviors, beliefs, desires, intentions, emotions, traits, attitudes, etc. Three of these mental states are particularly relevant in collaborative learning situations, namely inferences about partners' knowledge, behavior, goals (intentions). Study 1 focused essentially on inferences about peers' intentions while study 2 investigated inferences about peers' behavior. Our on-going study focuses on the inferences about peers' knowledge that is expected to be important in collaborative learning.

Our current empirical studies investigate the mutual modeling process in conceptual learning. The goal of these experiments is twofold. Our theoretical question is whether or not the mutual modeling effort enhances collaborative learning gains. Our methodological question is to capture the mutual modeling mechanisms. In order to avoid the 'anticipation' and 'rationalization' biases, we use interaction analyses and parallel gaze analysis. We are therefore using two eye-tracking machines and we perform an automatic comparison of the eye paths of both learners as in (Richardson & Dale, 2005). These experiments use the two mutual modeling prostheses described in the introduction, awareness tools and scripts. In both cases, subjects start by reading a text individually (Phase 1) and then have to build a concept map together (Phase 2). In the first experiment, the independent variable is an awareness tool available during Phase 2: A is informed of B's knowledge on three different chapters of the learning material; this knowledge has been previously measured through a pre-test at the end of Phase 1. In the second experiment, different scripts are implemented by providing subjects with complementary partial texts (jigsaw script) or conflictual texts (argumentation scripts) in phase 1. Both of these experiments manipulate the mutual modeling process in complex collaborative learning situations. Awareness tools about peer's knowledge (and behavior in general) may trigger mutual modeling facilities whereas the 'collaborative scripts' may strain effort of mutual understanding and by extension, enhance mutual modeling and perspective taking and making efforts. In a circular (if not spiral) manner, this increased mutual modeling effort may elicit interaction processes such as audience design, mutual regulation, elaborated explanation asking and providing, which are known to be beneficial for learning.

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Acknowledgments

We gratefully acknowledge the contribution of Fabien Girardin, Khaled Bachour and Kamni Gill. These researches are funded by the Swiss National Science Foundation (grant #102511-106940).

Tools of Play: Coordinating Games, Characters, and Actions While Learning to Play Video Games

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Abstract: This paper describes an individual's role in coordinating a distributed system for learning. The analysis deals with a core issue for CSCL; the mismatch between common measures for learning, which are based on individual traits and outcomes, and learning processes that are distributed across people and artifacts. Rather than bridge this mismatch through an assessment of group performance, we suggest that learning scientists consider assessing an individual's adaptive reorganization in a socio-technical system. We selected video game play as a context for looking at collaborative learning because it represents an emergent social activity young people commonly engage in. Additionally, recent claims that game play involves deep learning have not been thoroughly investigated with ethnographic research; this project begins to address that gap.

Introduction: Game play as collaborative learning

Empirical research on collaborative learning tends to rely on the traits and outcomes of individuals with the consequence that the accuracy of the collaborative learning process is not well accounted for (Barron, 2003; Stahl, Koschmann, & Suthers, 2006; Stevens, 2000). Although members of the CSCL community have long argued that learning occurs across people and artifacts, assessments still tend to focus on individuals. Broadly speaking studies of activity that take a distributed, cultural-historical, or situated perspective articulate a tension between an individual's agency and the context (Billett, 2006; Latour, 1996). In other words, for the field there is a great deal more to know about how individual agency operates in relation to the broader socio-technical system. Here we approach this issue by looking at an individual's role in naturally occurring instances of collaborative game play. Through a descriptive analysis we argue that the individual's agency plays a role in creating a suitable context for collaborative learning. From the analysis we suggest that one way to think about how to account for learning in the context of collaboration is to look at an individual's coordination of resources, specifically tools. By looking at how individuals coordinate tools we forefront the collaborative process, yet at the same time account for the individual's role.

Data sources and methods of analysis

The data we present here comes from a six-month ethnographic study of young people's game play. The study was conducted as part of a broader effort to understand how people learn across settings such as school, work, and home (Bransford et al., 2006; Stevens, 2000; Stevens & Hall, 1998; Stevens, Wineburg, Herrenkohl, & Bell, 2005). Our decision to study game play extended beyond a specific interest in games themselves. Rather game play was studied because it is how many young people choose to spend their time. Therefore, we find it is important for learning scientists, seeking to understand learning across a range of settings, to investigate this pervasive aspect of young people's lives. Consequently, we use the player rather than the game as the unit of analysis.

Game play lends itself well for looking at naturally occurring instances of collaborative learning. Video games have been held up as holding a promising future for education and the learning sciences (Gee, 2003; Squire & Barab, 2004), however little is known about what young people do while playing video games. The lack of detailed descriptions of game play has contributed in part to divisive debate on whether games are good or bad, rather than a conversation about how young people learn and use video games in their everyday lives. Additionally, many game systems are designed for use in social settings (i.e. the family living room) and come with multiple controllers to encourage use by many people at one time. At the same time, collaboration is not assigned but an emergent activity.

We visited eight participants on a weekly basis in their own homes for six-months. The specific population was chosen to represent a range in age (9-15), gender (4 boys and 4 girls), social configuration (2 sets of siblings, some participants played with friends while others played alone), and the type of games played. The participants selected and played their own games on their own systems, allowing for naturally occurring conditions during field visits. While the participants played, we video recorded activity that occurred in the room where the participants played along with activity that was taking place on the game screen. Later we synchronized the two images, 'in-room' and 'in-game', into a single file. We then content logged the videos (totaling over 100 hours) with written descriptions of activity across the game and the room. To address specific research questions we used the descriptive content logs to build cases, such as the one presented below. The benefit of having both the in-game and in-room recordings is that a "separate worlds" view of game play is avoided (Stevens, Satwicz, & McCarthy, in press). The separate worlds view holds that games exist apart or separate from other aspects of the players' lives and can lead to an inaccurate picture of how games are learned and their impact young people's lives.

Here we present the play of one individual involved in the study as a case of collaborative learning. "Johnny" was 13 years old when the study took place. He enrolled in the study with his older brother "Mikey" (age 15) and on several occasions (as the analysis shows) the two boys played together. Johnny and Mikey also have a younger sister, "Maddy" (age 8), who played with them and observed their play on a few instances. Johnny was selected for this particular analysis because his play occurred in a setting that involved a great deal of social interaction. Johnny also worked through a defined series of challenges in a particular game during the study period allowing for a view of progression in-game that can uncover the collaborative learning process.

Coordinating a distributed socio-technical system for collaborative learning and play

This analysis illustrates how Johnny gathers a system for collaborative learning. He does this by coordinating people, games, characters, and actions into a tool kit for playing games. *Coordination* is used as means to understand the assembly of people, media, and knowledge for learning and accomplishing tasks (diSessa, 1991; Hutchins, 1995; Stevens & Hall, 1998).

The analysis includes instances that can be seen as collaborative learning; they involve multiple people developing shared meaning while working together on a common problem (Stahl et al., 2006). Here learning is taken as "adaptive reorganization in a complex system" (Hutchins, 1995, p. 289). We use this particular definition to frame the analysis because it does not presume learning as a process relegated only to cognitive activity; "the relevant complex system includes a web of coordination among media and processes inside and outside the individual task performers" (Hutchins, 1995, p. 289). As a concept then, the complex system, or *socio-technical system*, is useful when considering how young people interact with video games and other media that make up the context in which games are played. In addition, we take a distributed view of collaboration, where activity is seen as distributed across people and material objects (Becker, 1982; Hutchins, 1995; Latour, 1996; Pea, 1993).

In the following analysis we describe Johnny's development of a 'tool kit' for accomplishing tasks in video games:

> [T]he term 'tool' refer[s] to not only tools in the traditional sense, e.g., objects like hammers, but more generally any socially constituted structure used to accomplish a particular task, including documents and standardized work practices. 'Tool kit' refers to the ensemble of materials deployed for the accomplishment of a particular task. (Goodwin & Goodwin, 1998, p. 91)

Our analysis looks specifically at three tools present in Johnny's play: 'games', 'characters', and 'actions.' Game is used consistently with its everyday meaning; it refers to the media purchased and played on the computer system. Characters are agents in the game, controlled either by the player or the computer, upon which activity is often centered. Actions refer to commands the player gives to the machine for use towards some outcome in the game.

Johnny's tools for play: games, characters, and actions

Take the following organizational setup, present during a field visit, as an example of how people, games, characters, and actions are coordinated in a socio-technical system for collaboration. Throughout most of the visit Johnny sat on the couch in the family's living room with his older brother, Mikey, and his younger sister, Maddy. They played three games during the visit across two different game systems. Some of the games were played concurrently or discussed while another game was being played. Concurrent play was possible because two game systems were present: a console game system played on the family's TV screen and a handheld game system.

The visit started and Mikey was playing *Dragon Ball Z Budokai Tenkaichi* on the PlayStation 2, while Johnny was playing a *Mario Brothers* game on the Nintendo DS handheld game system. After about 18 minutes of play, the two boys switched games. It is here that we can see how labor is divided in the context of their play. At this particular moment, Johnny was returning to the room after having left to check on dinner. Mikey was attempting to get past a particular challenge in the *Dragon Ball Z* game, where he had to stay alive in a battle against the character Majin Buu until the counter on the screen ran out.

Segment 1

1. ((Johnny runs into the room.))
2. Johnny: She got an all meat pizza] but it wasn't baked yet.
3. Mikey: [Oh! This guy is hard.
4. ((Johnny takes the controller from Mikey.))
5. Johnny: Majin Buu, can I try?
6. Mikey: yeah, I can't survive two minutes.
7. Maddy: he's too tough=
8. Mikey: =now if it was my job to beat him I might be able to do it.
9. Johnny: um ya know that place I couldn't get to earlier?
10. ((Johnny reaches into the couch and pulls up his Nintendo DS and hands it to Mikey.))
11. Johnny: Well it's now open and I'm in it. So run back get the red um, box. Float up, get the red coin on one of the windowsill thingies.
12. Mikey: What are you talking about Johnny?
13. Johnny: There's a red box. ((Johnny turns to look at the Nintendo DS screen in Mikey's hand.)) That!
14. ((Johnny turns to look at the TV screen, which is still loading the game.))
15. Johnny: And the reason he's got Wario's voice is because I'm Wario with Mario's head on. (2 sec.) So just=
16. Mikey: =you just float up here?
17. ((Johnny turns to look at the Nintendo DS screen in Mikey's hands.))
18. Johnny: Float over there.
19. Mikey: [(inaudible)
20. Johnny:]no float more more
21. ((Johnny turns to look back at the TV screen which is now playing an introduction to the battle Johnny will face.))

[Johnny and Mikey 2006-January-06_00:17:38.27]

At this moment Johnny and Mikey coordinated the available tool kit for accomplishing tasks in the two games they were playing. The coordination was preceded by Mikey's comment, "Oh! This guy is hard" (Segment 1 line 3), a statement that indicates he had assessed his own progress a specific task. Johnny then made a bid to take on the task, "Majin Buu, can I try?" (Segment 1 line 5). Johnny included a clarifying question by leading his bid with the name of the character Mikey was attempting to defeat, Majin Buu. The character, to be defeated, then was a part of the tool kit Johnny and Mikey used for defining tasks in the context of play. Mikey agreed to the change by handing over the controller and giving an affirmative verbal response (Segment 1 lines 4 and 6). In this exchange the controller signified who was responsible for the defined task and so it is not only a tool for controlling the game, but an organizational device for marking roles in the room. Mikey also described the parameters of the task at hand--survive two minutes (Segment 1 lines 5-7).

Johnny, though, did not leave Mikey empty handed and literally gave him the Nintendo DS along with a task to complete in the game (Segment 1 lines 9-21). The explanation of the task, however, took several turns and the use of additional tools. Johnny initially described the task with information on where in the game he had been; "ya know that place I couldn't get to earlier?" (Segment T line 9) and "I'm Wario with Mario's head" (Segment 1 line 15). The game characters, Wario and Mario, were used as tools to describe the task. Additionally, actions in the game were used as tools to define the parameters of the task. This occurred when Johnny told Mikey "run back get the red um, box. Float up, get the red coin on one of the windowsill thingies" (Segment 1 line 11). Johnny's explanation included several actions in the game: run, float up, and get the red coin. Mikey however requested additional information (Segment 1 line 12), which Johnny responded to by using Mikey's current actions in the game (Segment 1 lines 13 – 21).

We chose the particular moment transcribed in Segment 1 to illustrate the tool kit that had been coordinated in Johnny's socio-technical system for play. An obvious element of the system is his brother Mikey, who Johnny has enrolled into both his *Mario Brothers* and *Dragon Ball Z* games. The two games played at this moment constitute one type of tool in the distributed system; as seen in the information Johnny passed onto Mikey each game has a particular local history of play. A second type of tool are the game characters and the degree to which they define play in the game by creating task parameters and are employed to complete those tasks. A third type of tool is actions in the game used to accomplish specific tasks.

Near the end of same the field visit another person was enrolled into the socio-technical system. At the moment, Johnny was playing the *Mario Brothers* game on the handheld system and Mikey and Maddy were still playing *Dragon Ball Z Budokai Tenkaichi*. The phone rang and Johnny's mother brought it to him. On the line was a friend of Johnny's. His mother's description of the activity that was about to ensue was accurate: "They play video games while talking about video games on the phone." *[Johnny and Mikey 2006-January-06_01:27:58.29]*

Mikey grabbed Johnny's attention during the phone conversation to point out something on the television screen. Johnny then mentioned to his friend that Mikey was playing *Dragon Ball Z* to acquire characters to play with later (see Segment 2).

Segment 2

1. ((Mikey and Maddy are in between battles in the *Dragon Ball Z* game. Mikey points to the screen and gets Johnny's attention. Johnny is playing the Nintendo DS and on the phone with a friend discussing video games.))
2. Johnny: ((Talking to his friend on the phone.)) Woah. Mikey is helping me with um the Dragon Ball Z that I got for Christmas and he got me Kid Trunks and all these characters, it's so awesome.

[Johnny and Mikey 2006-January-06_01:29:12.18]

Johnny's comment can be taken as a partial description of the activity in the room, which included collecting characters in *Dragon Ball Z*. Collecting characters or items in games is generally done by completing levels or challenges. In this case, Mikey was working through a series of battles set within a storyline that encompasses the *Dragon Ball Z* game. Johnny's comment, that Mikey got him "Kid Trunks and all these characters, it's so awesome", can be taken as a reference to game characters as a part of a tool kit for play.

At the particular moment, while Johnny was on the phone, at least three other people were a part of the socio-technical system in which he played. His brother Mikey was hard at work, throughout the entire field visit, collecting characters for future play. On the phone was a friend with whom Johnny consulted by sharing knowledge of the games he was playing. His sister Maddy was being apprenticed into the system by acting in a peripheral role to the overall effort in *Dragon Ball Z* (Lave & Wenger, 1991; Stevens et al., in press). Although each person was there to play, they each had a role in adding more game characters and actions to the socio-technical system. By adding characters and actions, the tool kit at their disposal became better equipped for completing a range of tasks.

Within Johnny's social group, access to certain tools, such as actions in particular games, is assumed. Johnny and Mikey described the assumed tool kit in response to a hypothetical question we posed about a friend that needed help with some of the games that Johnny liked to play (see Segment 3).

Segment 3-1

1. Tom: What about you Johnny? Pick out one of your favorite games here, uh maybe the Tony Hawk, was that, you said one of your fav-- Or the Dragon Ball Z?
2. Johnny: yeah
3. Tom: If somebody came to you and said ya know, 'I just got it.' Let's say your friend just got it at school or something like that=

Johnny disputed the situation as we framed it and remarked that no one would ask for help on *Dragon Ball Z* (see Segment 3-2 line 4), the game Mikey was helping him with in Segments 1 and 2. He contended that "everyone's already an expert at it" (Segment 3-2 line 6) because five *Dragon Ball Z* games existed prior to the one we asked about. Johnny then likened our question to an older more culturally established game, *Pac-Man*.

Segment 3-2

4. Johnny: =ah, nobody would ask for help on Dragon Ball Z though.
5. Tom: Why is that?
6. Johnny: I don't know, cause there's already been five games and everyone's already an expert at it.

7. Tom: mmhum
8. Johnny: And it would be sort of weird. It would be like saying, 'how do you play Pac Man?'
9. Tom: hum
10. Mikey: yeah, it's=
11. Tom: =it's that basic?
12. Mikey: Yeah, really basic fighting game.

The assumed tool kit Johnny and Mikey described includes button sequences, which are used to create actions in the game (Segment 3-3). Mikey held up an older game controller and pointed out how these actions remain consistent, to some degree, across games and gaming systems through conventions built physically into the controllers. Across game systems, controllers take a similar form or in Mikey's words; "every system has this general idea on the right side, it's got a square turned that way." In the case of the game Mikey was describing, each button corresponds to a certain skateboarding action in the game. This indicates that there is an inertia built into the socio-technical system that makes taking up new games easy (Becker, 1995).

Segment 3-3

13. Tom: What about Tony Hawk? Is that the same way?
14. Mikey: [uh Tony Hawk is
15. Johnny:] It's the same for every system and that one's had twelve games for different systems.
16. Mikey: yeah, cause every system has this general idea on the right side, it's got a square turned that way ((Mikey holds up a Super Nintendo controller and points to the four buttons arranged in a square on its right side.)) and this is grid, this is jump, this is special, and this is another special ((Mikey pushes each of the four buttons while he explains what they do in the game.)) And eh- everyone's played a Tony Hawk game once in their life and you've played one, you've played 'em all. The only thing that improves is gameplay and graphics but controls stay the same.

Johnny described how the button sequence used to create an action could change from game to game in the same series. His explanation shows that he had committed to memory two specific sequences to use a "super attack" in the *Dragon Ball Z* games (Segment 3-4 lines 21 and 23). Each of these button sequences is a part of his gaming tool kit.

Segment 3-4

17. Tom: Controls stay the same, is that true across a lot of games you think or?
18. Mikey: uh, [no
19. Johnny:] no because on the original Dragon Ball Z Budokai game
20. Tom: mhum
21. Johnny: it was a side scroller and it was just a basic fighting game like Tekken, so you had to do punch punch punch punch then energy to do a super attack.
22. Tom: unhun
23. Johnny: but on this one you only have to power up for a few seconds and hold L-one and then triangle to do the super attack.
24. Mikey: yep

[Johnny and Mikey 2006-January-12_00:05:46.12]

Learning to use new tools

Johnny, like many players faced numerous choices within the play of each game. One of the more recurrent activities across games is the selection of a character for use in the game. In Segment 4 Johnny selected a character for use in the game *Super Smash Brothers Melee* (SSBM). At this particular moment he was playing what is called the "events mode" where there are a series of fifty scripted challenges on which a player can work over time. Throughout the six-month study Johnny returned to this portion of the game several times and worked to complete nearly all of the events. The transcript below shows that on one occasion Johnny asked for information on the characters to complete the challenge he had selected.

Segment 4

1. ((Johnny has just completed an event in SSBM. As it finishes he says, "Yes, another one done"))
2. Tom: you're rolling today, hun?
3. Johnny: yeah. Trophy Tussle three. (2 sec.) ((reading from the screen)) here's your shot for ma-joria's mask.

4. ((Selects "Lv. 47. Trophy Tussle 3" and a screen comes up where he must select a character to use in the challenge.))
5. Johnny: hmmm, who can take down many people?
6. ((Selects the character Ness and begins to work on the event.))

[Johnny and Mikey 2005-November-17_01:18:38.13]

Segment 4 began just after Johnny had completed one event and was in the process of moving to another yet uncompleted event (Segment 4 lines 1-4). After selecting an event, he had to choose a character from a group of 25. While he was making his selection Johnny verbally indicated a quality in the character he was looking for, the ability to "take down many people" (Segment 4 line 5). The twist in this particular instance is that Johnny and the researcher were the only two people in the room. While Johnny did on occasion ask for assistance with games from the researcher, it usually took the form of asking if he noticed something that had happened in the game or had access to particular resources (such as the Internet). In general the researcher made it a rule to not offer any help. Additionally, Johnny's intonations and body positioning would indicate he did not direct his comment to the researcher. From this it is inferred that Johnny's request is not to another person, but to himself.

Soon after the moment in Segment 4, Johnny successfully beat the event, something he was unable to do several months earlier indicating that Johnny had made some progress in the game. The question he asked while choosing his character was, however, not new and was present during an earlier field visit where Johnny collaborated with his brother Mikey on the same event. On the first attempt the two boys tried for fourteen minutes and eighteen different attempts and were unable to beat the event. In comparison, Johnny beat the same event in two attempts and two and a half minutes after the moment transcribed in Segment 4. Between the two attempts Johnny changed his character selection. In the instance transcribed in Segment 5, Johnny and Mikey attempted to learn how to use the character, Jigglypuff, to beat the same event Johnny successfully completed two months later.

Segment 5-1

1. Mikey: whoa. (3 sec) I think I'll just stay up here while he's invincible.
2. ((Jigglypuff is floating up at the top of the screen.))
3. Johnny: you only have five jumps and then you're-
4. (13 sec.)

In Segment 5-1 Mikey and Johnny had a short exchange about how to use the character Jigglypuff. Mikey's suggestion was that he would use a particular action, jump, to float on the top of the screen. Johnny then pointed out to him that there are a limited number of jumps that he can use. This short moment points to some variance in how this particular tool, the character Jigglypuff, can be used. As the segment went on, Mikey continued to struggle and asked Johnny for help (Segment 5-2 line 9). The play in this instance also indicates that assigned expertise changes between the boys (Stevens, 2000).

Segment 5-2

5. Mikey: Jigglypuff needs a brick move.
6. (23 sec.)
7. Mikey: This totally stinks they keep putting shells right in the middle.
8. (6 sec.)
9. Mikey: why isn't it working.
10. (4 sec.)
11. ((Mikey pauses the game.))
12. Johnny: Mikey.
13. Mikey: press Z.
14. ((Mikey gets a "failure". The game screen returns to the events menu. The same event is selected; Johnny is now controlling the action on the screen.))
15. Mikey: It just doesn't work.
16. Johnny: That's because you weren't doing the right moves.
17. Mikey: Yeah I was=
18. Johnny: =Mikey you were only doing down B. She's got more moves than down B.

[Johnny and Mikey 2005-September-16_00:05:17.07]

After Mikey asked why Jigglypuff was not working Johnny responded that he was not “doing the right moves” (Segment 5-2 line 15). Johnny’s response points to a particular set of actions, these so-called “right moves”, that are used with the character Jigglypuff. His use of the phrase “right moves” implies that there are also a set of ‘wrong moves’ that should be avoided. These actions (the “right moves”) are a part of the tool kit Johnny has amassed for playing in the gaming context. Segment 6, which occurred just prior to Segment 5 is an example of how the actions of a character were discussed. Mikey had suggested that with Jigglypuff he would be able to kill all of the other characters with one hit, which would have helped them meet the event’s objective (Segment 6 line 2). Johnny disagreed, and contended that the other characters would “wake up too fast” and Mikey countered his point by providing a strategy for using the action (Segment 6 lines 3 and 4). In instances such as this the tools in-hand for the players--characters and actions--were discussed in relation to their utility for particular tasks leading to the development of knowledge for using the tools.

Segment 6

1. ((A battle begins on the screen. Johnny is controlling a character on the screen and fighting a computer controlled character.))
2. Mikey: I need to do that Majora's Mask one cause I know how to kill everybody in one hit. (2 sec) Jigglypuff! (singing)
3. Johnny: They wake up too fast=
4. Mikey: =No you don't even need to make 'em sleep you just get right in the middle of all of 'em and you'll kill at least one with a sleepy attack.
5. ((Johnny switches the game back to the events menu screen.))

[Johnny and Mikey 2005-September-16_00:02:26.11]

Johnny and Mikey's attempt to beat the Trophy Tussle 3 event, partially transcribed in Segment 5, included the development of an action, Jigglypuff’s sleepy attack, for the purpose of completing the event. The development of this in-game action between the two boys occurred early in the study as well. What follows in Segment 7 is an instance of play in which Johnny attempted to explain to Mikey how to use this action while they competed against each other in a multiplayer mode of the game SSBM. Notice that development of an in-game action was a collaborative in-room activity despite the fact that they were playing against each other. This shows one of the ways that unmandated collaborations emerge, through the development of a tool kit for accomplishing tasks.

Segment 7-1

1. ((Johnny, Mikey, and their sister Maddy are in a battle against each other in the game SSBM. Jigglypuff, Mikey's character, spins, lets out a bright flash and is thrown back.))
2. Johnny: Mikey you don't even know how to use it.
3. (8 sec)
4. ((Jigglypuff, Mikey’s character, again spins on the ground, but is thrown across the screen by Zelda, Maddy’s character.))
5. Mikey: Ok, yeah it's official- it's official I don't know how to use Jigglypuff.
6. Johnny: You just hold 'B' and release it. (4 sec.) ((Jiggypuff spins on the ground.)) now release it.
7. Mikey: No I wanted to see her say—

Mikey attempted to use Jigglypuff’s sleepy attack and was unsuccessful (Segment 7-1 lines 1-7). Immediately following Mikey’s try Johnny gave him specific instructions in coordination with the activity on the screen (Segment 7-1 line 7). The sequence points to the coordination of two tools, a character and an action, in an instructional moment.

Segment 7-2

8. ((The battle continues for about 40 seconds.))
9. Mikey: ((Jigglypuff spins on the ground.)) is that how you do it? ((Peach, Johnny’s character, knocks Jigglypuff off the screen.)) no that is apparently not how you do it.
10. Johnny: Mikey you just hold 'B' in and release it. ((Jiggiypuff spins on the ground starts flashing and Zelda flies off the screen.))(3 sec) there you go.
11. Mikey: ohhh

12. Johnny: yeah, who would have ever figured out that
[Johnny and Mikey 2005-July-14_00:48:50.01]

The instructional sequence transcribed in Segment 7 ended with Mikey successfully completing Jigglypuff's sleepy attack. The instance is a glimpse into how characters and actions become tools for use in the play of video games. Particular tasks not only require a tool kit that contains the right characters and actions, but knowledge of how to use the tools. Although Mikey and Johnny were competing against each other at the particular moment they both collaborated in building the socio-technical system. By helping Mikey develop as a player, the tool kit Johnny used for playing games was distributed across multiple people.

The collaborative development of a new tool

Johnny also worked collaboratively with players other than Mikey when developing his set of actions. On a different date Johnny and a friend, Evan, developed an action in the game, *Teenage Mutant Ninja Turtles 2: Battle Nexus [Johnny and Mikey 2005-August-19]*. The action was developed to solve a specific problem the two boys were having. During the course of their play Johnny and Evan were given a challenge by the game in text; "*Take Fugitoid to a secure place. Just pick it up and carry it with you. It won't be a nuisance that way. There's a way out from the rear of the back street.*" Johnny and Evan struggled with this task because they were unable to figure out how to pick up Fugitoid as the directions indicated. The struggle was the result of a missing action in their tool kit.

While figuring out how to carry Fugitoid the boys introduced a variety of actions into the socio-technical system. These actions include: moving forward without Fugitoid, pushing Fugitoid, and throwing Fugitoid. Some of the actions partially worked but none of them lead to a successful completion of the task. Johnny and Evan also attempted to introduce resources external to the game into the system to help figure out how to pick up Fugitoid. These resources included: the researcher as a knowledge source, the Internet, and a guidebook. None of the resources were immediately available so the boys continued on without them. Eventually Johnny threw Fugitoid in what might be considered an "accident" or "random" occurrence, however at the moment Johnny was going through the possible button combinations. These combinations are limited by the physical nature of the controller.

Segment 8

1. ((Johnny's character moves away from Fugitoid and Evan's moves in closer.))
2. Evan: Did you press all the buttons?
3. Johnny: ye:::s. I tried every single combination of buttons
4. ((Johnny is pushing systematically through the buttons on the controller. His character is at the front of the screen and responds to each of the button combinations.))
5. Johnny: (2 sec.) wait I thought I- (4 sec.) darn I thought that was grab (4 sec.) I had it for a second.
6. Evan: what? pick up=
7. ((Johnny's character bends down slightly as though he is going to pick something up.))
8. Johnny: =there!
9. Evan: what is that?
10. ((Johnny's character moves towards Fugitoid and picks him up briefly, flipping Fugitoid over his back.))
11. Evan: Oh you flipped him. How'd you do that?
12. ((Johnny's character picks up Fugitoid and carries him on his back.))
13. Evan: Yes. How'd you do it?
14. ((Johnny's character throws Fugitoid over a ledge towards their final destination.))
15. Evan: There we go, how'd you=
16. ((Johnny pauses the game.))
17. Johnny: You hold L and press B or A I can't remember
18. Evan: ok hold on, let me try.
19. ((Johnny's character flips Fugitoid over his back.))
20. Evan: Hold L=
21. Johnny: =push A
22. Evan: I'll do it I'll do it (3 sec.)
23. ((Evan's character is next to Fugitoid, but he is not picking him up.))
24. Evan: I can't do mine
25. Johnny: Hold L- get out of the way.

26. Evan: maybe it's B (inaudible) I'm not gonna be able to do it.
27. ((Evan's character goes up to fight the attackers. Johnny's character goes and picks up Fugitoid.))
28. Johnny: R
29. Evan: R? R and what?
30. Johnny: R and B
31. Evan: 'k just=
32. Johnny: =I'm carrying him
33. Evan: just keep walkin. pick him up again. I'll protect you.

[Johnny and Mikey 2005-August-19_00:25:27.09]

In Segment 8 there are several relevant moments to the development of the tool kit used in their game play. Lines 1-9 include Johnny's attempt to systematically find a new action, ending with the recognition that something significant had happened; "there!" After Johnny and Evan recognized that a new action could be used to accomplish the task they refined it (Segment 8 lines 10 – 27) and committed the button sequence to memory (Segment 8 lines 28 – 33). In this particular instance Johnny and Evan learned a new action by using their existing tool set, including the inertia present in the conventions of the controller. They then coordinated the action with other aspects of the socio-technical system to accomplish an emergent task.

Discussion

The analysis here looks across Johnny's play to understand how one accomplishes the work of playing a video game. Johnny's play includes the development and coordination of tools for use in a socio-technical system. The tools are means by which he interacts with the game to accomplish a set of emergent tasks. Johnny's success in solving game tasks is a result of his adaptive reorganization in the socio-technical system over time. This description of collaborative learning is a case of tool coordination—games, characters, and actions—for use across people within the system. The descriptions are useful for thinking about how to understand an individual's role in a collaborative effort.

Learners like Johnny adaptively reorganize tools in the system by bringing multiple disparate elements into coordination (Stevens & Hall, 1998). In this case, Johnny expanded his tool kit and developed the knowledge required to use the new additions. This reorganization occurred across both people and artifacts. Some of the actions Johnny committed to memory, while characters remained saved in the game system. What should be recognized is that in many of the instances there was an emergent self-assessment of the tool kit that led to a reorganization of the system. Johnny and his collaborators looked at what was and was not working. They also took feedback from the game system and each other. For example, take the instance above in Segment 1 when Johnny and Mikey switched games. At that moment, Mikey's comment, that the task was difficult, set the stage for a reorganization in which Johnny took over one task while handing another over to Mikey.

Learning as reorganization in a socio-technical system has potential if we can document instances where tools are developed in the pursuit of tasks meaningful to the learner. It is easy see the activity Johnny was engaged in as a non-consequential despite the ubiquity of game play. However, his coordination of tools towards accomplishing specific tasks is remarkable. It involves a network of people whose assigned expertise changes on a moment-to-moment basis (Stevens, 2000). The coordination makes use of an inertia (Becker, 1995) built into the media and other objects; however, players such as Johnny create their own tools for working within this system. Tasks emerge from use of the tool kit, rather than an externally mandated source. Additionally, the collaboration was not mandated, rather it was a function of how tools were coordinated to accomplish the emergent tasks.

This suggests that accounts of learning in collaborative settings might benefit from a component that evaluates an individual's reorganization of the socio-technical system. This echoes some of the ideas behind Preparation for Future Learning assessments, where the focus is not whether an individual is able to immediately solve a problem in a new setting but on how well the individual is prepared to learn how to solve new problems (Bransford & Schwartz, 1999). However rather than focus explicitly on cognitive processes inside the head, the description above indicates that the development tool kit is an aspect of how one learns in a collaborative setting.

One point that should not get lost here is that the learning in these instances is not programmed or designed into the media. It was an active process where the participant developed a tool kit for working and learning in the context of games. This is consistent with the perspective Suchman (1987) articled in regards to help systems built into copy machines; that AI systems are a resource for action rather than a programmed plan. In Johnny's case the programmed aspects of the game were tested against his conception of how the coordinated tool kit worked. When progress was not made on the task at hand, he reorganized.

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Acknowledgements

This work was supported by a grant from the National Science Foundation (NSF#0354453). Any opinions, findings and conclusions expressed here are those of the authors and do not necessarily reflect the views of the NSF. We also want to thank Laurie McCarthy for her role in the Gaming to Learn project, along with Lari Garrison and Heather Toomey Zimmerman for reading earlier drafts of this paper.

Video Traces: Creating Common Space between University and Public Schools for Preparing New Teachers

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Abstract: The preparation of new teachers has been an enduring issue of the field of education (Handbook on Research on Teaching, 1963; 1973; 1986; 2001). The objectives of this paper are to describe the interaction among different stakeholders in teacher education facilitated by a novel technology-based approach, *Video Traces*. The analysis suggests that this is a potentially effective approach for making mutual learning across public school and university-based teacher educators more concrete, visible and compelling. In our paper, we (a) present an overview of the pedagogical philosophy that guided the design of the *Video Traces* medium, (b) describe the enduring problem in teacher education we are using *Video Traces* to address, and (c) present data and analysis from our approach in the context of North American educational system.

Theoretical framework

Tensions between views of teaching and teacher preparation as constructed in university and public school contexts constitute one of the most pervasive and enduring problems in the work of teacher education. Feiman-Nemser and Buchmann cleverly characterized this as the "two worlds problem" over two decades ago (Feiman-Nemser & Buchmann, 1985). The two worlds problem refers to the tensions between pre-service teacher preparation at the university and the in-service classroom practice. Approaches to resolving some of these tensions have involved various proposals for creating a "third space", in which university and public school educators could join in collaborative dialogue and inquiry around teaching and learning (Goodlad, 1994; Holmes Group, 1986). In addition, there needs to be more direct and compelling evidence of learning outcomes for teachers if institutional commitments to collaboration among arts and sciences, education and school-based faculty are to be sustained over time (Teitel, 2001).

The *Video Traces* (see Figure 1) is a software medium that gives the users ability to annotate voice, pointing, and drawing to "common objects" in visual forms such as still images and audio-video files (Stevens, 2005). The *Video Traces* medium supports features such as concrete and durable records of conversations and natural modalities of looking, pointing, and talking.

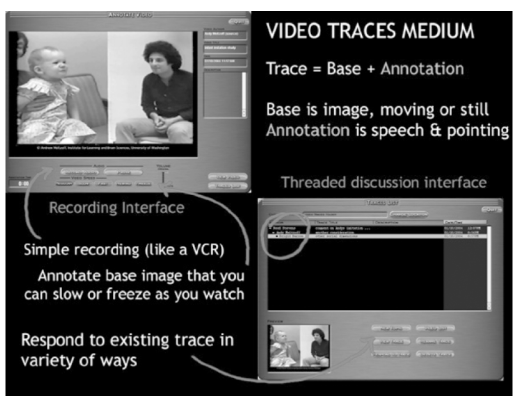

Figure 1. *Video Traces* software medium

In our study, the Teacher Education Program of a major research university (PNU) in the Pacific Northwest, public schools, and *Video Traces* came together to prepare new teachers. The student teachers scan student works from their classrooms and import them in *Video Traces*. These scans and videos are called bases. Then they annotate the bases, in *Video Traces,* via a microphone connected to the computer. In addition to audio annotation, student teachers also use the pointing and drawing tools in *Video Traces* to "jointly attend" to what is being referred to in the recorded questions. This combination is called a trace. Fellow student teachers, classroom teachers, university faculty and supervisors reviewed and responded to these traces in the same manner. In terms of digital file formats, a trace is an audio-video file combining an image or a video with a voice and pointing overlay. A trace thread is the sequence of response traces to an initial trace.

Data analysis and findings

The analysis of actions and events in *Video Traces* is framed using concepts and techniques, such as interactional sequence, from Conversation Analysis (CA) adapted to new technologies (Goodwin & Heritage, 1990; Hutchby, 2001). The data for this study are 73 traces that were created within 23 threads by participants from May 2005 to November 2005. The participants were two each of student teachers, school faculty, university faculty, and one university supervisor. The traces were exported as audio-video files and transcribed using simplified conventions of CA. The start and end points of gestural annotations were located in transcripts within parentheses. This paper briefly reports on two categories of events—traces as recycling of questions and the traces as archival resources. Due to space limitations, we have included data presentation only for the first category.

Traces as Recycling of Questions

The thread featured Maya as student teacher, Anu as co-operating teacher, Jaya as university faculty, and Lakshmi as another student teacher. A very brief data excerpt is presented in the Figure 2 below.

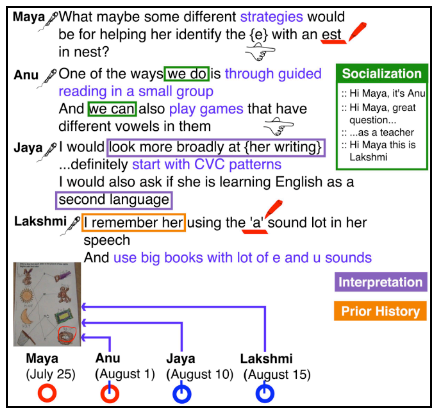

Figure 2. The figure shows a transcribed excerpt from the trace thread. The audio annotation is marked with mic icon, pointing annotation with hand icon and the drawing annotation with the red pen icon. The analysis is marked with boxes and further referenced with categories such as socialization etc. The different strategies are marked in lighter color. The bottom section shows the chronological sequence of trace thread.

Maya, in her initial trace, introduced the student and referenced the student work to the viewer by using the natural modalities of pointing, drawing and speech available in the medium. Maya described the student's work, gave her observations, and asked about the different strategies. Anu (school based faculty) responding to Maya's trace greeted her by name. She "thickened" Maya's description by detailed descriptions. Anu suggested three strategies. Jaya (university faculty) complimented Maya on her question and responded with three suggestions about student assignments, classroom practices such as small group guided reading, and ESL strategies. Lakshmi (student teacher) introduced herself and reviewed Maya, Anu, and Jaya's traces. She brought up her prior interaction history with the student as a teacher and made observations about student's pronunciation and speech patterns. Lakshmi based her observations in Jaya's suggestion of working on pronunciation as well as on visual representation.

The different collaborators in the teacher education process came together to interact around the student's work as if they were in the same classroom. The analysis of the individual traces across the collection showed that the users created traces; to analyze practice around student's works, to ask, to address content and practice specific questions, and to interpret and present hypotheses regarding literacy practices. The users took up the different suggestions and hypotheses in their practice and responded as new traces. In this manner, the users embodied traces in their classroom practice over and over again. This embodiment is defined in this study as recycling of questions.

This category of analysis relates to the "recycling of questions and consequently, of the knowledge"(Ladson-Billings, 1994). The recycling, as defined by Ladson-Billings, is situated in the discourse between the teacher and the student in a classroom. In this study, the recycling of questions is spread asynchronously across time and space between a student teacher, her peers, and teacher educators. This recycling creates a common space around classroom activity.

Traces as Archival Resources

The thread featured Maya as student teacher, Sudha as university faculty, Anu as co-operating teacher, and Lakshmi as another student teacher. Maya started her trace with a description of classroom practice. The description was adapted from Anu's thickened description earlier in the findings section. Maya asked conceptual and procedural questions about the student's practice. She ended her trace by asking for advice and suggestions for strategies. Sudha (university faculty) introduced herself to Maya. Sudha then set up a small scenario to model possible engagement with the student in response to Maya's conceptual and procedural question. She made another suggestion of using stories as tools to understand math concepts. She supported Maya's way of engaging the student and pointed out that the student's practice is linked to the classroom practice. Lakshmi reviewed Maya and Sudha's traces. In her response, Lakshmi inferred from an earlier trace discussion between her and Sudha in a different trace thread. Her suggestions to Maya were referred from that discussion. Anu referenced Sudha's suggestion of story contexts. She stated that she would be using these ideas in her own practice and modeled a scenario for the next academic year.

The second category is informed by Shulman's advocacy of teaching in which "the principled skills and the well-studied cases are brought together in the development and formation of strategic pedagogical knowledge" (Shulman, 1986). The findings suggest that the traces can function as 'cases' to inform the routine indeterminacy of classroom practice. Within the thread, the different users reviewed and responded to previous traces. The users entered specific conversations but they also entered different kinds of conversations from their disciplinary perspectives. Within the collection, the threads act as archival resources. The users refer to specific suggestions from other threads while making their traces. There is an increased sophistication in framing questions and offering interpretations. In this manner, the threads serve as documented and referred cases of student teaching and learning.

Educational importance of the study

In our study, we have used a novel technology-based approach of *Video Traces* to bring public school-based and university-based teacher educators together in mutually beneficial and visible discussions on teaching and learning. Our analysis shows that the participants made traces that captured student learning in classrooms, analyzed those situations, noticed teaching practices, interpreted those practices in broader contexts, made hypotheses, and offered suggestions for further work in the classrooms. The traces created from this collaborative dialogue and inquiry present evidence of student teacher learning in actual classrooms and serve as documented cases. The creation of common space mediated by *Video Traces* distributes the onus of "thinking like a teacher" (Kleinfeld, 1992) and acting like a teacher collectively among the human and technological resources of the partnership. The findings from our study suggest that the technology-based approach of *Video Traces* supports novice teachers in their actual classrooms and creates a "third space" to bring university and public-school-based teacher educators together in the teacher education process.

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Process Gain: A Task on Which Real Groups Outperformed Individuals Modeled Under Perfect-Knowledge-Sharing Assumptions

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An experiment with university students examined effects of two versions of a statistics task on individual versus group learning. Using a novel measure of transfer, groups were found to outperform, on average, individuals modeled as groups under perfect-knowledge-sharing assumptions. To my knowledge, this is the first result of its kind, and it suggests a characterization of naturally productive collaborative tasks.

Process loss occurs when a group performs worse than their capability due to a member with the correct answer being silent or ignored by the other group members (Steiner, 1972). The idea is that something in the group process must have caused the group not to recognize and take up the correct answer even though it was available to them. This is a pattern frequently noted in small group interactions (e.g. Barron, 2003), and it continues to be a concern of educators and researchers looking to implement effective collaborative learning activities.

If groups performed up to their potential, then ideally, every member within a group would perform at least as well as the best member of their group. One way that this could occur is if the students in a group selected the top performer in their group to do every problem and explain the answers until everyone in the group understood them. I am not suggesting this is an ideal form of cooperation; far from it. Instead, it seems like an important and attainable benchmark. Currently, most-competent-member levels of performance are rare and noteworthy (e.g. Laughlin, Zander, Knievel, & Tan, 2003).

Even top performers are wrong sometimes, so their performance can be surpassed. If every member of a group shared their knowledge perfectly with one another, and they could all recognize a correct solution when they saw it, then they would outperform or at least equal the top individual. This hypothetical scenario reflects what should happen under perfect-knowledge-sharing, and it is known as the *truth-wins* scenario. Unlike the most-competent-member model, whenever *any* individual in the group has the correct answer, it is assumed that the whole group will take up that answer. Ideally, collaborative activities would naturally promote perfect-knowledge-sharing amongst group members such that truth-wins levels of performance were achieved.

Of course, we would like groups to be able to construct new understanding by building upon each member's insights and incomplete conceptualizations. This achievement is known as process gain because something in the group interaction leads students to a new understanding that no individual had before working together. When process gain occurs, it is possible for groups to exceed even truth-wins levels of performance. Such results have been obtained in group performance tasks. For example, Schwartz (1995) found that dyads were more likely to make a conceptual shift on a gear modeling performance task than individuals modeled under truth-wins assumptions. On learning tasks, case studies have shown instances of building insight and knowledge construction between group members (Yackel, Cobb, & Wood, 1991); however, to my knowledge no study has shown a task on which the average group member exceeded truth-wins levels of performance.

Finding and characterizing a type of learning task that naturally yielded process gain could be theoretically and educationally significant. According to recent survey results, despite many teachers knowing of means of structuring productive collaborations, they often do not implement them because they are already so busy (Antil, Jenkins, Wayne, & Vadasy, 1998). Below is a study of a statistics task for college students designed on the innovation and efficiency framework of Schwartz, Bransford, and Sears (2005). It was hypothesized that tasks with an opportunity for innovation followed by efficient instruction might yield naturally productive interactions and, thereby, process gain.

Methods

Participants—Seventy-six university students with little or no background in statistics were randomly assigned to one of two conditions: Innovation or Efficiency. Participants either worked alone (40) or in same-sex pairs (36). Forty-eight women (24 in dyads) and 28 men (12 in dyads) participated.

Materials—A nine-page learning packet about the chi-square formula and a seven-item posttest made up the materials for this experiment. The learning packet consisted of three units about different aspects of the chi-square formula. Each unit contained three pages: a Lesson page, a Problems page, and a Final Practice Example page with answers provided at the bottom of the page. For Innovation, the sequence of pages for each unit was: 1) Problems, 2) Lesson, and 3) Final Practice Example. For Efficiency, the sequence was: 1) Lesson, 2) Problems, and 3) Final Practice Example. In other words, Innovation had to try to figure out a formula before getting the canonical solution while Efficiency received the formula and had a chance to apply it.

A key feature of these materials was that the Problems pages had contrasting cases designed to highlight key features of the formula(s). For example, if students did not divide by the expected value for the problems in the first unit, then two of the three contrasting cases would yield the same value. Not many students would spontaneously realize the need to divide by the expected value, but when they were shown to do so in the lesson, they should recognize its importance. It was expected that participants in the Innovation condition would be more likely to notice and learn from these contrasts than those in the Efficiency condition.

Time participants spent on the learning packet and time on the posttest was recorded. The posttest consisted of seven problems of three types. Two problems required calculations of the chi-square formula, three involved comprehension questions about where and how the formula works, and two involved a difficult transfer to the related statistics topic of inter-rater reliability. An important feature of these far transfer measures was that they were designed in PFL fashion (Bransford & Schwartz, 1999; Schwartz & Martin, 2004). The first problem introduced the new type of problem while the second provided a more difficult case in which those same principles applied. The PFL idea is that only participants who were prepared to learn from the first problem, the resource problem, would be able to answer the second one, the target problem, correctly. This approach allows one to estimate what kinds of instruction are better at preparing students for future learning.

Procedures—Table 2 summarizes the procedures. To keep participants from blurring the distinction between conditions, they were told to complete each page in the packet before going to the next page and to look back only if necessary (such as to recall the formula). The experimenter instructed participants to spend 25 minutes on the posttest, that it was difficult, to try their best, and to work alone. Some participants finished early, and none took longer than 30 minutes. No significant differences between conditions were found on time taken for the learning packet or the posttest.

Table 2: Procedures

Step	Context	Innovation	Efficiency	Time
1	Alone / Dyads	9-page Learning Packet on the Chi-Square Formula		35 to 65 min.
		1) Problems (invent) 2) Lesson (instruction) 3) Final Example (reinforce)	1) Lesson (instruction) 2) Problems (apply) 3) Final Example (reinforce)	
		Short Break		~5 min.
2	Alone	Posttest (done individually) (7 problems: 2 calculations, 3 comprehension, 2 far transfer)		25 min.

Results

Each of the seven problems on the posttest had multiple components that could receive points. For example, did the participant divide by the expected value? Did they calculate the expected value and the chi-square formula correctly? Did they show negative transfer by applying the chi-square formula blindly where it did not belong? The coding scheme showed high inter-rater reliability (93% agreement, minimum agreement of 80% on any item, Cohen's Kappas above 0.81 for each type of question: calculation, comprehension, and far-transfer). The reliability of the test was also high (alpha = .81).

As expected, participants in the Innovation condition outperformed those in the Efficiency condition on the far transfer problems while performing similarly on the calculation and comprehension problems, as shown in Figure 2. Some may argue that the better performance of the Innovation condition on the transfer problems was simply due to "greater messing around." The data suggest otherwise. Innovation participants made fewer negative transfer errors than their Efficiency counterparts ($\chi(1) = 5.40$, $p = .020$). In other words, they were better at adapting their knowledge to solve novel problems, and they better understood when the chi-square formula did *not* apply. Perhaps most importantly, on the preparation for future learning (PFL) measure the Innovation condition not only outperformed the Efficiency condition, the Innovation dyads outperformed their individual peers—both on average, and under truth-wins assumptions. These results are shown in Figure 3 where Innovation "nominal" dyads' and Efficiency "nominal" dyads' scores were calculated based on the performance of the individuals from the Innovation and Efficiency conditions, respectively. Those interested in how the truth-wins calculation was performed can contact the author.

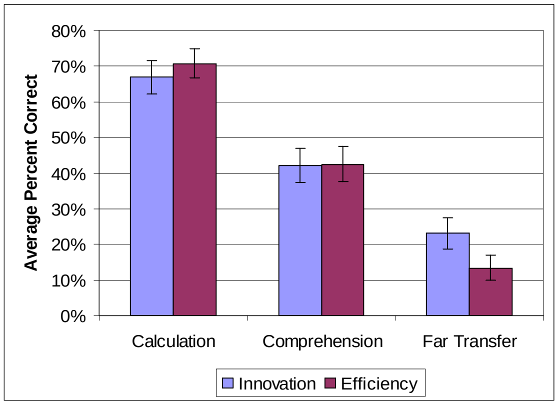

Figure 2. Performance under Innovation versus Efficiency learning conditions on learning and transfer measures.

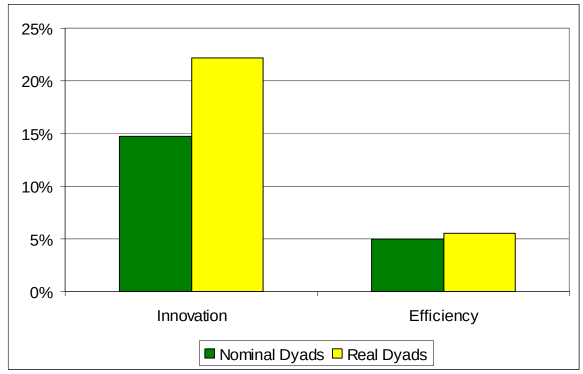

Figure 3. On the target question, real Innovation dyads exceeded all others.

Conclusion

In the field of collaborative learning, many important discoveries have been made about effective methods for obtaining educational benefits from group work. Teachers often do not implement some of the research-based structures for making collaborative activity effective (Antil et al., 1998). This study took an alternative approach, examining what types of tasks might naturally support productive collaboration. Using the innovation and efficiency framework of Schwartz et al. (2005), two versions of a statistics task for college students were developed. The efficiency version followed traditional lesson-then-practice methods while the innovation version included an opportunity for inventing solutions to contrasting cases prior to receiving the lesson. The innovation condition significantly outperformed the efficiency condition on far-transfer problems, and innovation dyads exceeded the performance of their individual peers modeled as dyads under perfect-knowledge-sharing assumptions.

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Improving Young Learners' Scientific Understanding in CSCL Environments

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Abstract. The purpose of the present study was to improve young learners' scientific understanding in CSCL environments. The study consisted of two phases: Phase I for fostering a collaborative learning culture, and Phase II for using Knowledge Forum as a CSCL tool. Primary 3 students in one Singapore school participated in this study. Findings suggested that while students were motivated to learn in CSCL environments, they had difficulties monitoring and sharing knowledge for their own understanding. Additionally, a great deal of teacher guidance was needed to encourage student participation in collaborative knowledge building processes. Overall, this study may imply that students at this early stage of schooling need more structured guidance to improve their understanding in CSCL environments.

Introduction

The main purpose of the project in the present paper was to build a culture of classroom practices that are grounded in collaborative learning and knowledge building, which is known as the Knowledge Building Community model (Scardamalia & Bereiter, 1994). Knowledge Building is based on the concepts of communal constructivism (Meehan, Holmes, & Tangney, 2001) and situated learning (Lave & Wenger, 1991) whereby communities of learners construct a communal knowledge base through interaction, inquiry, discussion and reflection. For knowledge to be constructed by the community of learners, a *culture* needs to be enacted in which learners interact with each other in collaborative ways. With the culture of knowledge building in place, the additional interactive dimension of technology systems, e.g., Knowledge Forum (KF), a computer-supported collaborative learning (CSCL) environment, can then be incorporated to further enhance the discussion, sharing, reflections on and retention of that communal knowledge pool (Bielaczyc & Collins, 2006). The emphasis of the project was placed on employing collaborative inquiry-centered pedagogy, instead of traditional didactic pedagogy deeply rooted in many classrooms, in order to foster a collaborative knowledge building culture. After the process of collaborative culture building, Knowledge Forum was employed as a medium to facilitate the process of scientific knowledge building among students. This paper reports on early findings of the three-year plan of fostering and building CSCL environments at one primary school in Singapore.

Theoretical framework

Basically, the main theoretical framework is to help students learn how to collaboratively work with others, how to inquire knowledge, and how to reflect on their thinking process in CSCL environments. Specifically, this study is based on Knowledge Building, "defined as the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts."(Scardamalia & Bereiter, 2003). In the classroom, Knowledge Building is usually initiated by a theme of inquiry relevant to a topic. Ideas and questions that the students have about the theme are then articulated and posted in a discussion forum as notes. Knowledge forum then acts as a communal database where the ideas are seeded and improved. As the participants engage themselves in the various means of advancing, they challenge each other's ideas through building new notes or revising existing notes. This phase is essentially a social process mediated by knowledge-building discourse that focuses on sharing new knowledge, synthesizing new knowledge with prior knowledge, detecting gaps in understanding, co-construction of theory and so on. Eventually, it leads to the growth of the database which reflects the progress of the community as a whole.

Research Methodology

Participants of this study included Primary 3 students in a Singapore school. The majority of the students come from homes with low to middle SES. Among various subject areas, this study focused on Science lessons. Using a design experiment (Brown, 1992) as a methodological approach, the research team designed lesson plans and lab activities with the Science teachers. The intervention strategies employed collaborative learning and knowledge building activities involving heterogeneous groups of pupils of varying ability levels in the classroom prior to the introduction of Knowledge Forum as a learning tool. Mixed methodology was employed to provide multifaceted perspectives of the research questions. Qualitative data included classroom observations, student artifacts (e.g., think cards, worksheets, KF postings, etc), and interviews with selected students. Quantitative data on the rate of learning achievement was collected based on the mastery of instructional objectives as stated in the school curriculum.

Research findings of Phase I and II are presented in the present paper. The main purpose of Phase I was to foster a collaborative learning culture in classrooms. It should be noted that that since our aim was to build up a collaborative knowledge building culture prior to the introduction of a Knowledge Forum as a collaborative learning tool, all the activities in Phase I were carried out without any online activities and technology components. Basically, students participated in learning activities that were designed around the principles of Knowledge Building (Hewitt & Scardamalia, 1998) in the following order:

1. *Trigger activity and Idea Generation* – the knowledge building pursuit starts with a trigger activity to encourage students to generate ideas and questions on the theme or topic, and to write down these ideas and questions on specially designed think cards;
2. *Idea Connection* – the teacher then guides the students into the process of searching for classifications to connect the ideas generated on the think cards, and these classifications are visually constructed using a knowledge web of think cards;
3. *Direct Teaching* – this is the part where the authoritative voice of the teacher is heard, providing the initial impetus and framework for the students to start searching for information to create their individual and communal knowledge base;
4. *Laboratory activities* – these are experiments, either within a laboratory or outdoor setting, designed to help students in their search for information and knowledge;
5. *Reflections on laboratory activities* – these reflections are scaffolded by questions on reflection sheets to help students think about what they have learnt, how this new knowledge has helped them in answering their initial questions about the theme or topic of study, and what new perspectives of knowledge has been built from the laboratory activities;
6. *Individual and communal pull-together* – this is the activity, initiated by the teacher, that guides the students into looking at the knowledge that each individual has built from the preceding activities and to draw the individual strands into a group and communal pool of knowledge built up on the theme or topic for study.

Next, the purpose of Phase II was to improve student understanding of science principles and concepts in a CSCL environment where Knowledge Forum was employed as a technological tool. Instead of using think cards, students used Knowledge Forum to share their ideas. Students worked collaboratively with 4-5 group members.

Results

Rather than discussing data in a separate manner, findings from data analyses were integrated to provide a clear picture of what happened in the early stage of the implementation. At the end of the term, a test consisting of 13 items from knowledge building units (Magnets and Materials) and 17 items from non-knowledge building units (Living things & Non-living things) was administered to measure student understanding. A statistical analysis showed that there was no significant difference on test scores between knowledge building units (M=57.83, SD=22.14) and non-knowledge building units (M=60.72, SD=15.85). While it may be thought that employing collaborative knowledge-building activities could reduce performance on traditional types of assessments, this result can be interpreted that there was no negative effect on traditional measures. The analysis of observations indicated that students were motivated by trigger activities and Knowledge Forum. Students perceived that starting a lesson with a trigger activity and idea generation was quite different from typical lessons where teachers directly introduce lesson topics from textbooks. In the focus group interviews, students mentioned that they enjoyed working with friends during Science lessons as they could learn from their friends' ideas.

While it was encouraging to discover the students' increased motivation in CSCL environments, several issues were identified as problematic. One of the biggest problems was lack of idea improvement. The analysis of think cards and KF postings revealed that the initial ideas of many students were rarely improved. Although lab activities and reflection times were employed to encourage students to improve their ideas over time, student ideas generally consisted of isolated facts with little explanations. This result might be related to lack of resources for idea improvement. The analysis of the data from the focus group interviews revealed that many students had limited access to resources other than the Science textbook. This was especially true of the students from low SES families, of which there was a majority in the school. Many of these children do not have home access to computers and the Internet. They also did not search for additional information from books available in the school library. As for the small number of children who had home access to computers and the Internet, their web surfing largely consisted of games rather than Science-related searches. Additionally, the analysis of the observation data revealed a lack of collaborative learning. Although the students carried out their knowledge building activities in collaborative learning groups, there was little evidence of collaboration in the learning process among the group members. Activities in science labs and computer labs were conducted collaboratively, but the learning process was individual rather than collaborative. Specifically, little KF postings were connected to other postings and few students posted questions to other groups.

Conclusion

Building a CSCL environment is a difficult endeavor, especially in classrooms where students have little exposure to collaborative learning approaches. Our results showed that while it is critical for students to monitor and build knowledge for their own understanding, they had difficulties developing such skills. Although attempts were made to improve young students' science learning through scaffoldings such as think cards, reflection sheets and Knowledge Forum, results revealed that students in this study needed more specific scaffolding strategies. Additionally, results of the present study are consistent with previous studies that found a great deal of teacher guidance is needed to encourage student participation in collaborative knowledge building processes (Caswell & Bielaczyc, 2001; Hewitt, 2001). For instance, teachers need to help students see the value of building knowledge for their own understanding, instead of completing tasks given by a teacher (Hewitt, 2001). Overall, this study may imply that students at this early stage of schooling need more structured guidance toward reflective inquiry learning in CSCL environments.

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Constructing new knowledge in collaboration: instructional support for improving information pooling and processing in groups

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Groups can build valuable new knowledge by drawing inferences from their members' complementary knowledge. Unfortunately, groups tend to focus on information known to all members from the start ("shared") and neglect members' unique ("unshared") knowledge. The present study investigated whether a similar bias could also be found at the level of inferences drawn from shared and unshared information. In an experiment, 27 student dyads solved a murder mystery task over a videoconferencing system. A control condition was compared to two instructed conditions which were informed about typical task difficulties, and either received external guidance from a collaboration script (script condition), or planned their own collaboration (planning condition). Dialog analyses revealed the expected biases towards shared information in both the pooling of text information and the drawing of inferences. Instructional support helped dyads to produce more correct solutions, but did not improve the drawing of inferences.

Groups of learners and problem solvers can profit greatly from pooling and integrating their members' complementary knowledge. In particular, new knowledge can be built at the group level by drawing inferences from the information contributed by individuals. This collaborative pooling and integration of information enables the co-construction of new shared knowledge (Roschelle & Teasley, 1995) and the generation of more advanced problem solutions (e.g. Rummel & Spada, 2005). Thus, it is an important aspect of successful collaboration (Meier, Spada, & Rummel, 2007). Unfortunately, groups tend to focus on information that is known to all members from the start ("shared") and neglect members' unique ("unshared") knowledge. For this reason, groups typically fail to detect the best solution in "hidden profile" situations, where the best alternative can only be found if all available shared and unshared information is pooled (see Wittenbaum, Hollingshead, & Botero, 2004 for an overview). Experimental research on the effects of information sharedness on group discussion, however, has so far focused on the mere pooling of information and neglected higher levels of information processing, i.e. the collaborative construction of new knowledge. The present study therefore 1) investigated whether biases towards shared information can also be found at the level of inferences, and 2) explored two kinds of instructional support for overcoming such biases.

The task: solving a murder mystery

Dyads of university students collaborated on a murder mystery case over a desktop-videoconferencing system. Each student first read a set of "interrogation protocols" individually, which had to be returned after 30 minutes. The dyad was then given 50 minutes to discuss which out of four suspects had most likely committed the murder, and to justify their decision. To succeed, students had to draw 12 inferences from both shared and unshared pieces of information, yielding the motive, the alibi, and one further piece of evidence for each of the four suspects. The task was a "hidden profile" in that the unconnected, individual pieces of information pointed towards the wrong suspect, while the inferences pointed towards the murderer. All participants were informed that their sets of information differed to some extent, that they had to return all materials after reading them, and that they were supposed to find motives, alibis, and further evidence for the four suspects. In order to investigate the effect of information sharedness on information processing, three types of inferences were analyzed (Table 1):

- *"collaborative inferences"* from unshared information distributed between dyad members
- *"individual inferences"* from unshared information located with the same dyad member ("undistributed"), and
- *"common inferences"* from shared information.

The text information in the "interrogation protocols" was distributed between participants in such a way that each dyad could draw four collaborative, four individual, and four common inferences. Three different text versions of the murder mystery story were realized in order to not confound the sharedness of information items and inferences with the implications of their specific content. All data were aggregated over these text versions.

Table 1: Visualization of collaborative, individual, and common inferences (adapted from Härder & Spada, 2004)

Information	Person A	Person B	Type of inference
unshared, distributed			collaborative
unshared, undistributed			individual
shared			common

In line with the existing literature (Wittenbaum et al., 2004), our hypothesis was that more shared than unshared text information would be pooled. In addition, group members holding an interdependent pair of unshared, undistributed information should find this information more relevant (and probably easier to remember) than isolated pieces of unshared, distributed information (Fraidin, 2004). Our hypothesis concerning the three types of inferences was that common inferences should be the easiest type to draw, because they can be drawn individually by each member as well as collaboratively. Collaborative inferences, on the other hand, should be the hardest type to draw, because they can only be drawn collaboratively during discussion.

Videoconferencing setting

During collaboration, dyad members sat in adjacent rooms and collaborated via a desktop-videoconferencing system (VCON running with ViGO). This setting established controlled conditions in which all utterances and actions could be recorded. Dyads were provided with a shared text editor (Groove Office) which both students could access and edit at the same time. A first shared document contained a questionnaire in which students judged how likely each of the suspects had committed the murder, and wrote down their final decision. A second shared document served to collect information and collaboratively write down a justification for the joint solution. Both documents were available during the whole length of the discussion. Each student also received paper and pencil for individual note-taking. All dyads underwent a short technical tutorial prior to collaboration.

Instructional support

Three experimental conditions were realized: two instructed conditions, and an uninstructed *control condition*. Individuals in both instructed conditions were informed about typical task difficulties in advance of their collaboration on the murder mystery task: the existence of unshared information, the need to recall all information from memory during discussion, and the need to draw inferences in order to find a good solution. Dyads in the *script condition* were then provided with external guidance from a collaboration script (running on a second computer monitor) which prescribed four phases of work: Students were to first pool the available information thoroughly in their shared text editor, and then engage in a phase of individual recall in order to complete the information pool. In a third phase, students were told to search for interconnections between pieces of information, and to write down inferences regarding motives, alibis, and further evidence for all suspects. Finally, the script instructed students to summarize their information and make a decision. Structuring collaboration by means of collaboration scripts has proved an effective means of fostering the generation of new knowledge (e.g. Kollar, Fischer, & Hesse, 2006). Collaboration scripts, however, also bear the danger of reducing motivation, in particular if they run counter to participants' own strategies for effective collaboration and problem-solving (Dillenbourg, 2002). Therefore, the means of support employed in the second instructed condition, informed planning, aimed at facilitating self-regulation by prompting students to construct their own script, presumably more in line with their "internal collaboration scripts" (Kollar et al., 2006). Prior to the murder mystery task, dyads in this *planning condition* were given 10 minutes to discuss how they wanted to structure their problem-solving process. They were encouraged to write down their plan in an additional shared text editor that stayed available for them during problem-solving.

Design

Instructional support (control/script/planning) was realized as a between-subjects factor, and sharedness of information (shared/unshared undistributed/unshared distributed) as within-subjects factor. Fifty-four female students from various departments (except psychology) with an average age of $M=23.17$ ($SD=3.32$) years took part in the experiment. Dyads were randomly assigned to one of the three conditions ($n = 9$ dyads per condition). Dyads' collaboration was videotaped and later coded for relevant pieces of text information and inferences in students' discussion. The correctness of the solution served as an outcome measure.

Results and discussion

Analysis of students' dialogs revealed the expected effects of information sharedness. An ANOVA with information sharedness (unshared distributed/unshared undistributed/shared) as within-subjects factor, experimental condition as between-subjects factor, and pooled information as the dependent variable confirmed our hypotheses: Across all conditions, 71% of unshared distributed, 84% of unshared undistributed, and 93% of shared information was pooled ($F=11.44$, $p<.001$; partial $\eta^2= .32$). An ANOVA with the number of drawn inferences as the dependent variable also revealed a significant effect of information sharedness ($F=7.56$; $p=.001$; partial $\eta^2=.24$): Across all conditions, 49% of the collaborative inferences, 65% of the individual inferences, and 79% of the common inferences were drawn (compare Table 1). Thus, collaborative inferences emerged as the most difficult, as expected. Interestingly, the number of collaborative inferences drawn during discussion also showed the highest correlation with the probability rating students gave for the correct suspect in their solution ($r=.42$; $p=.03$). Thus, the integration of unshared, distributed information into new shared knowledge was indeed very important for finding a good solution. These effects go well beyond the existing literature on the effects of information sharedness in "hidden profile"-like situations on group information processing (e.g. Wittenbaum et al., 2004). For the field of CSCL, the findings may suggest that complementary knowledge is not only a great resource for learning, but also a significant challenge for successful collaboration that calls for support. However, more research is needed in order to find effective support measures. The instructional support realized in the present study, contrary to expectations, did not improve the drawing of inferences significantly. Nevertheless, it did lead to a higher number of correct solutions of the murder mystery case: All dyads in the two instructed conditions, but only 6 dyads in the control condition solved the case correctly ($\chi^2=6.75$; $p=.03$). This difference was probably mediated by a stronger focus on inferences in the uptakes during discussion in the instructed conditions. However, this effect did not reach the .05-level of significance ($F=3.09$; $p=.06$; partial $\eta^2=.21$). We assume that a more difficult task would have been necessary in order to detect differences between experimental conditions.

To better understand the processes involved in the collaborative drawing of inferences, a descriptive analysis of the patterns in which inferences were actually drawn during discussion was performed, that will inform further approaches towards supporting the collaborative drawing of inferences from distributed information. A follow-up study is planned to explore more specific support measures, both in the form of instruction and in the form of technical tools embedded in the collaboration environment, and evaluate their effects with the help of more difficult task materials.

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Acknowledgments

This work is being funded by the Virtual Graduate School "Knowledge Acquisition and Knowledge Exchange with New Media" of the German Science Foundation (www.vgk.de).

Meaning making in CSCL: Conditions and preconditions for cognitive processes by groups

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Abstract. Meaning making is central to the interactions that take place in CSCL settings. The collaborative construction of shared meaning is a complex process that has not previously been analyzed in detail despite the fact that it is often acknowledged as being the distinguishing element in CSCL. Here, a three-minute excerpt from a discussion among three students is considered in some detail. The students are reflecting on their analysis of mathematical patterns in a synchronous online environment with text chat and a shared whiteboard. Several interaction methods and group cognitive processes are identified. The analysis suggests a number of conditions and preconditions of such interaction. These are necessary for achieving the potential of CSCL as the accomplishment of high-order cognitive tasks by small groups of learners. An understanding of the conditions and preconditions of the small-group meaning-making process may aid in the design and analysis of CSCL activities, as well as in the development of a theory of group cognition.

The uniqueness of CSCL

The vision of CSCL is that networked computers can bring learners together in new ways and that shared digital environments can foster interactions that produce new understandings for the groups and their participants. Accordingly, the uniqueness of CSCL pedagogical and technological designs consists in their techniques for supporting group interactions that can solve problems, gain insights, build knowledge. To guide design, CSCL theory needs to explicate the processes by which groups accomplish these cognitive tasks and to specify the preconditions for such interactions to take place.

In the formative days of the history of CSCL (see Stahl, Koschmann, & Suthers, 2006), collaboration was defined as "a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand… a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995, p. 70). The study of collaboration so defined suggests a shift away from the psychology of the individual to the small group as the unit of analysis, and a process-oriented focus on the socially-constructed properties of small-group interaction: "Empirical studies have more recently started to focus less on establishing *parameters* for effective collaboration and more on trying to understand the *role* that such variables play in mediating interaction" (Dillenbourg *et al.*, 1996, p. 189, emphasis added). These re-definitions of the object of research differentiate *an approach to CSCL interested in group cognition* from the orientations of educational-psychology studies of individual learning in settings of cooperation and/or distance learning.

CSCL has been defined explicitly in terms of the analysis of *meaning making*. A keynote at CSCL 2002 proposed: "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" (Koschmann, 2002, p. 18). Recently, this approach has been re-conceptualized as studying the "practices of understanding" (Koschmann & Zemel, 2006). At the CSCL 2005 conference, a research agenda for the field was proposed in terms of "intersubjective meaning making" (Suthers, 2006b). This emphasis has a two-fold implication. It suggests that empirical studies investigate the processes of meaning making that take place in the studied settings. But also, in theoretical terms, it implies that we should be analyzing the nature of shared meaning and the structures of small-group meaning-making processes in general.

For all the talk about meaning making, there has been little empirical analysis of how meaning is actually constructed in small-group interactions. It is generally assumed that meaning is created and shared through processes of interaction, communication and coordination. But the nature of these processes is taken for granted. Even a special journal issue on "Meaning Making" presents alternative analyses of a particular interaction recording and reflects on the methodologies used, but never explicitly discusses what is meant by the term "meaning making" (Koschmann, 1999). Similarly, a recent book devoted to the topic of *Meaning in Mathematics Education* concludes that "various aspects of communication which may affect the construction of meaning are discussed. On the other hand, the problem of the construction of meaning itself is not really tackled" (Kilpatrick *et al.*, 2005, p. 137).

For some time, I have been trying to work out structures of collaborative meaning making. At ICLS 2000, I presented a model of collaborative knowledge building (Stahl, 2006b, Ch. 9), followed at CSCL 2002 with a theoretical framework for CSCL (Stahl, 2006b, Ch. 11). In an extended analysis of building collaborative knowing illustrated with my SimRocket data, I presented elements of a social theory of CSCL centered on meaning making (Stahl, 2006b, Ch. 15). I subsequently distinguished between interpretation from individual perspectives and meaning as shared and embodied in artifacts in the world in my CSCL 2003 paper (Stahl, 2006b, Ch. 16). At CSCL 2005, I argued that groups can think, that they can have cognitive agency (Stahl, 2006b, Ch. 19). My book on *Group Cognition* develops this notion that small groups of learners—particularly with the support of carefully crafted digital environments—have the potential to achieve cognitive accomplishments, such as mathematical problem solving. Here, the term "group cognition" does not refer to some kind of mental content, but to the ability of groups to engage in 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. Thus, the theory of group cognition is similar to theories of distributed cognition, but now the emphasis is more on distribution among people rather than with artifacts, and the cognitive accomplishments are high-order tasks like math problem solving rather than routine symbol manipulations.

Recently, my colleagues and I have been investigating specific structures of meaning-making practices, analyzing online interactions among math students. For instance, we characterized "math-proposal adjacency pairs" (Stahl, 2006d), looked at how a group could solve a math problem that none of its members could solve (Stahl, 2006a), and investigated how students used a referencing tool in our environment (Stahl, 2006c). We try to closely analyze brief interactions in well-documented case studies to determine the social practices or methods that groups use to accomplish their meaning making. Thereby, we seek to determine structures of small-group cognitive processes. We believe that the foundation of CSCL as a unique field of study is the investigation of the meaning-making processes that take place in online collaborative settings. The analysis of intersubjective meaning making or group cognition is not the whole story; one can, of course, also analyze individual learning and other psychological phenomena or larger activity structures and communities-of-practice, but we believe the processes of small-group interaction are of particular centrality to CSCL.

A case of group cognition

Although meaning and related topics like grounding have been debated for millennia, they have usually been discussed using examples that were made up by the authors to seem like natural, commonsensical interactions or using data from laboratory conditions. To study interaction "in the wild" or with examples that occurred in real-life situations is a new and important approach that we can borrow from ethnography (Hutchins, 1996) and ethnomethodology (Garfinkel, 1967). However, finding cases of interaction that are relevant to CSCL research interests cannot be left up to chance. CSCL research aims to inform technological and pedagogical design. Therefore, cycles of design-based research are often appropriate. One must put students in situations where they are motivated to pursue certain kinds of tasks in particular kinds of environments. The situations must be instrumented to capture an adequate record of the interactions that take place.

In this paper, we will observe meaning making in a brief excerpt from Spring Fest 2006 of the Virtual Math Teams (VMT) service at mathforum.org. The collaborative context was set by organizing a contest: members of the most collaborative teams would win prizes. Students were recruited globally through teachers who were involved in other Math Forum activities. The team in the excerpt consisted of two students who apparently went to the same school and one from another time zone in the US, as well as a facilitator from the Math Forum, who provided technical assistance—this is all that either the students or the facilitator knew about each other. Pedagogically, the topic for discussion was an open-ended exploration of geometric patterns. An initial pattern of squares formed from sticks was given. The students were to figure out the formulae for the number of squares and the number of sticks at stage N first, and then explore other patterns that they or other teams invented. The technological environment combined text chat with a shared whiteboard. It included a referencing tool for pointing to areas of the drawing from chat postings (Mühlpfordt & Stahl, 2007). There was a supplementary wiki for sharing results between teams. To support the research methodology, all activities were logged. The chat and whiteboard could subsequently be replayed at any speed and stepped through. Virtually all aspects of the group interaction including everything that the participants knew about each other's actions were captured and available for analysis (see Table 1 and Figure 1).

Each team in Spring Fest 2006 met for four sessions over a two-week period. Each session lasted a little over an hour. At the end of each session, the teams were supposed to post their findings on a wiki for the other teams to read. Between sessions, the facilitators posted feedback to the teams on their whiteboards. The feedback generally acknowledged the team's accomplishments and suggested next steps. In the case considered here, the team was particularly encouraged to explain what they had done because it was not clear to the facilitators from the interactions that the team members always understood what each other was doing.

Table 1. A three minute excerpt of the chat log. Line numbers have been added and the delay in seconds from the previous message has been calculated.

line	participant	chat posting	time	delay
1393	Quicksilver	(a) was define the problem, (b) was the solution which we got...	07.29.46	
1394	bwang8	we calculated the # of square if the diamond makes a perfect square	07.29.48	2
1395	Aznx	We can define the problem.	07.29.48	0
1396	Aznx	We got the solutions.	07.29.55	7
1397	Quicksilver	yes	07.30.12	17
1398	Quicksilver	the added corners	07.30.16	4
1399	Aznx	But I'm not sure how to explain how we got to the solutions, although it makes prefect sense to me.	07.30.18	2
1400	Quicksilver	to make a square	07.30.19	1
1401	Aznx	I'm just not sure how to explain it.	07.30.24	5
1402	Quicksilver	and we found those were triangular numbers	07.30.25	1
1403	Aznx	Well, I can explain the second formula.	07.30.32	7
1404	Quicksilver	lets go step by step	07.30.35	3
1405	Quicksilver	NO!	07.30.37	2
1406	Quicksilver	we don't know hte second formula	07.30.42	5
1407	Aznx	It was done through the method of finsing the pattern of triangular #s.	07.30.45	3
1408	Aznx	Yes we do.	07.30.50	5
1409	Quicksilver	?	07.30.55	5
1410	Aznx	Suppose their second formula is our third.	07.30.56	1
1411	Quicksilver	That was taem c's tho	07.31.06	10
1412	Aznx	No.	07.31.12	6
1413	Aznx	They didn't do.	07.31.16	4
1414	Aznx	The nuumber of squares	07.31.20	4
1415	Quicksilver	ohj!	07.31.25	5
1416	Aznx	or the find the big square	07.31.26	1
1417	Quicksilver	that formula	07.31.27	1
1418	Quicksilver	i thot u meant the other one	07.31.31	4
1419	Quicksilver	yeah that is ours	07.31.36	5
1420	bwang8	point formula out with the tools so we don't get confused	07.32.37	61
1421	Aznx	So we're technically done with all of it right?	07.32.49	12
1422	Quicksilver	this is ours	07.32.51	2
1423	Quicksilver	all right...lets put it on the wiki	07.32.58	7
1424	Aznx	That is theirs.	07.33.02	4
1425	Quicksilver	adn lets clearly explain it	07.33.05	3
1426	Aznx	bwang you do it. =P	07.33.11	6

Pattern problems are commonly used in teaching the concepts of beginning algebra. The research literature on this shows that explaining solution paths is generally particularly difficult for students (Moss & Beatty, 2006). By pressing the students to explain their work in the wiki posting—and to prepare for this in their chat interaction—

we encouraged the creation of data that allows us to see something of how a group of students made sense of their mathematical problem solving and where they had difficulty in conducting group practices leading to understanding.

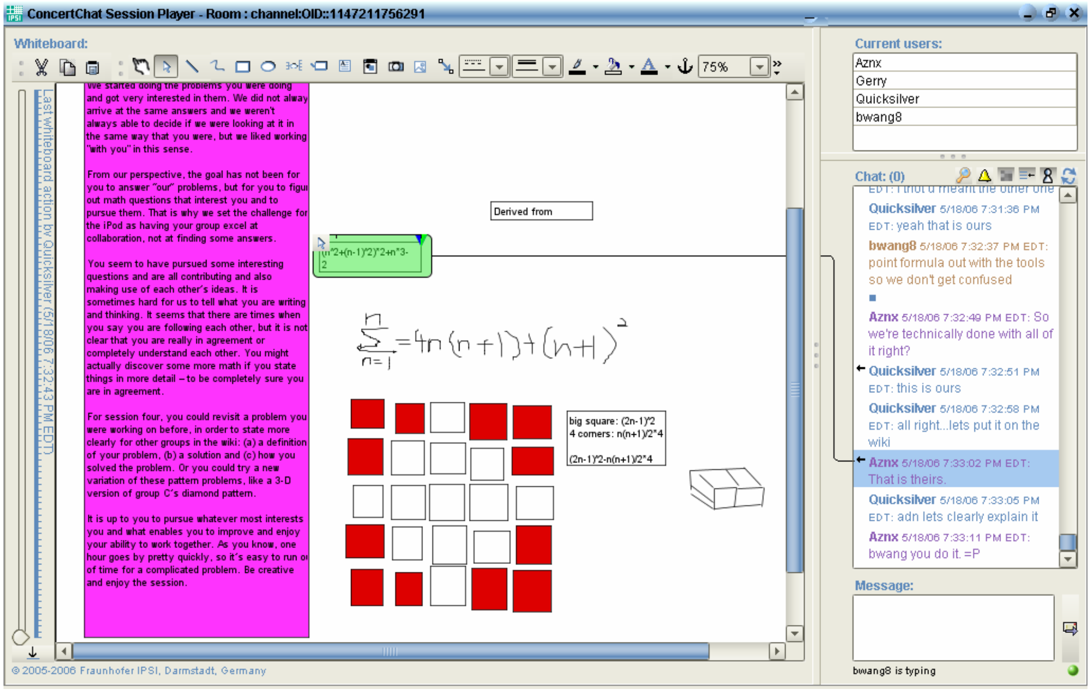

Figure 1. View of VMT-Chat environment during excerpt. The selected chat message appears as line 1424 in Table 1. Note the graphical reference from this posting to a formula on the whiteboard.

Analysis of the meaning making

At first glance, the excerpt in Table 1 seems hard to follow. In fact, that is why the VMT research group started to look at this segment in one of its data sessions. The postings themselves express lack of clarity (e.g., line 1410), inability to explain what is going on (line 1401) and confusion about what is being discussed (line 1418). In addition, it is hard to understand how the postings hang together, how the participants are responding to each other and making sense together. It is often informative to focus on such excerpts. When the taken-for-granted flow of conversation breaks down—seemingly for the participants as well as for the researchers—the nature and structure of the interaction is likely to be made explicit and available for analysis. For instance, in my SimRocket excerpt (Stahl, 2006b, Ch. 12), the students' shared understanding of the facilitator's reference broke down, and they had to work hard to make the reference successively more explicit until everyone saw it the same way. Similarly, the analysis of deictic referencing in the VMT environment (Stahl, 2006c) looked at how students combined available resources to define a math object that was not at first clear and that required considerable work to establish agreement on what was being referenced. In the excerpt in this paper, the meaning-making process is displayed by the participants as problematic for them—presenting an analytic opportunity for us as researchers to observe characteristics of meaning making rendered visible in their announced breakdown and explicit repair.

This is a common pattern in collaborative small group interactions. In our corpus of about 1,000 hours of online collaborative problem solving, it is frequently a driving force (as discussed in Stahl, 2006d). It becomes apparent to the participants that they are not understanding each other or do not know what references are pointing to. The participants gradually make more explicit what they mean or the object of their references, using various available resources in their environment or their communication media. Eventually, each participant acknowledges that they understand the others, at least well enough to continue what they were doing before they paused to repair their mutual confusion. Thus, the nature of collaborative processes work to align individual interpretations to a gradually shared meaning that is itself co-constructed in this process. In this way, "group cognition" is not something that exists somewhere outside of the interaction, but is a gradually emerging accomplishment of the group discourse itself (Stahl, 2006b). It is also important to note that the collaborative meaning-making process that produces the shared group meaning tends to produce in parallel individual interpretations of this meaning.

Accordingly, when the individual participants later leave the group, the understandings of the group accomplishment may remain available to the individuals and can be re-introduced by them in subsequent group interactions.

In our present excerpt, the students are responding to the feedback in the large text box in Figure 1, where the facilitators wrote, "For session four, you could revisit a pattern you were working on before, in order to state more clearly for other groups in the wiki (a) a definition of your problem, (b) a solution and (c) how you solved the problem." We can see that the students are oriented to this feedback because line 1393 translates it from a suggestion by the facilitators to the students ("you") into a summary by the students of what they ("we") should do. The students are hesitant to post a statement of how they solved the problem on the wiki for others—including, of course, for the facilitators who will be judging whether they are one of the best teams and deserving of a prize. So in line 1394, they begin to go over their solution path together. But lines 1395 and 1396 do not continue this review; they return to line 1393 to agree that they accomplished parts (a) and (b). It is ambiguous what line 1397 is responding to. The line is continued (by the same participant) in line 1398. To understand this new line requires recalling how the students solved the pattern problem in a previous session.

Look at the large diagram in Figure 1. The white (empty) squares form a diamond pattern of width 5 squares. The red (filled) squares fill in a large square encompassing the diamond, by adding 4 corners each composed of 3 red squares. One can compute the number of squares that it takes to form a diamond pattern by first easily computing the number of squares in the large encompassing square and then subtracting the number of squares in the 4 corners. This was the strategy used by the group in a previous session. If we now look at the sequence of postings by Quicksilver, we see that they make sense as a response to Bwang's posting. Quicksilver is taking up Bwang's description, recalling that the square was formed by adding the "corners" and then further specifying the strategy as treating the number of squares in a corner as being part of a "triangular number" sequence. Meanwhile, Aznx's postings in lines 1395, 1396, 1399 and 1401 seem to form an independent sequence of statements, focusing on the problem of step (c) from the feedback, explaining how the problem was solved. If we follow the sequences of different students, they seem to be working in parallel, with Aznx despairing of explaining the group solution path even while Bwang and Quicksilver are reviewing it.

It is a well-known phenomenon that chat technology results in confusion because the turn-taking rules of face-to-face conversation do not apply in chat. Participants type in parallel and the results of their typing do not necessarily immediately follow the posting that they are responding to. When more than two people are chatting, this can produce confusion for the participants and for researchers (Herring, 1999). Moreover, in an attempt to prevent postings from becoming too separated from their logical predecessors, people rush to post, often dividing their messages into several short postings and introducing many shortcuts, abbreviations, typos, mistakes and imprecision. Technological responses to this problem have been explored (e.g., Fuks, Pimentel, & de Lucena, 2006). Analytically, it is important to begin a study of a chat record by reconstructing the threading and uptake structure of the chat log. Threading specifies what posting follows what and when the structure diverges into parallel or unrelated threads (Cakir *et al.*, 2005). The uptake structure indicates which specific elements of a posting, gesture, reference, drawing action, etc. are building upon previous elements (Suthers, 2006a).

While Aznx (in lines 1395, 1396, 1399, 1401, 1403) and Quicksilver (in lines 1397, 1398, 1400, 1402) seem to be following their own independent threads, there are also increasing signs of interaction between these threads. While one is complaining that he (or she) does not know how to explain their solution path, the other is demonstrating a way of systematically explaining, or at least enumerating, the path. Aznx' "Well, I can explain the second formula" (line 1403) delimits his previous general statement that he could not explain their solution. Now he is stating that he can explain part of the solution—possibly the part that Quicksilver (line 1402) has just characterized as finding that the pattern of the corners followed the pattern of "triangular numbers" (from Pascal's triangle, which is relevant to many pattern problems). So line 1403 reacts to Quicksilver's 1402 as well as continuing from Aznx' own 1401. In chat, postings frequently continue a train of meaning making from the same participant as well as responding to a recent posting by another participant, thereby potentially contributing to intersubjective meaning making.

We have already seen that new postings do not only relate to previous postings. They also reference things outside of the immediate chat discourse. For instance, line 1393 made reference to the feedback displayed in the text box in the shared whiteboard. It did this partially by quoting an excerpt from the feedback and partially by transforming it from the facilitator perspective to the participants' perspective. Line 1402 referred to Pascal's triangle by using the phrase “triangular numbers” that the students had used before. Line 1403 refers to “the second formula.” The referent for this phrase is not obvious to the engaged participants or to us as retrospective analysts. Quicksilver says “No” in line 1405. This seems to be a response to line 1403 about the second formula, with 1404 being a response to 1401 and to the general problem of preparing an explanation for the wiki.

When references become unclear to some members of the discourse, it may be necessary to repair the breakdown in mutual understanding. A lot of important interaction in collaborative activities consists in such repair, clarifying the references by making them more explicit so that each participant comes to understand them well enough to continue the discourse (Koschmann & LeBaron, 2003). Clark’s contribution theory of grounding (Clark & Brennan, 1991) describes how this takes place among dyads in face-to-face informal conversation, illustrated with made-up examples. For online small groups using text chat in real examples of knowledge building, such as explaining math problem solving, the repair may be more complicated.

Quicksilver’s “No” is followed by, “we don’t know the second formula.” The phrase, “second formula” in line 1406 here is not referencing the same thing as “second formula” in line 1403, as indicated by the question mark in line 1409. In fact, it takes two and a half minutes and 21 postings (1403 to 1424) to reach the point where the discourse can go on. The confusion gets translated by line 1410 into which formula is this team’s and which was Team C’s solution that this team found on the public wiki. Aznx tries to clarify (lines 1413-1416) that the formula he is concerned with could not be Team C’s because Team C did not calculate the number of squares using the encompassing big square (they only proposed a formula for the number of sticks). Quicksilver describes his confusion, but the conversation does not continue; there is a one-minute silence, which is embarrassingly long in chat.

The silence is broken by Bwang’s suggestion in line 1420 to use the graphical referencing tool that is part of the VMT environment. As they wrap up the discussion, Quicksilver points to one formula (“ours”) in the whiteboard (line 1422) and Aznx to the other (“theirs”) (line 1424). This resolution of the confusion through the use of the available technology was thus accomplished by all three of them, using the referencing tool to point to objects in the whiteboard in coordination with labeling them with the terms “ours” and “theirs” in the chat. In parallel with this, the students propose to move on to post on the wiki: Aznx suggests that they may be finished preparing the explanation (line 1421). Quicksilver agrees, “all right, let’s put it on the wiki and let’s clearly explain it” (lines 1423, 1425). Finally, Aznx concludes the preparations by saying, “Bwang, you do it” (line 1426).

Ambiguity of the interaction

We can follow the discussion taking place in the excerpt now better than at first sight. Not only do we have some sense of its structure and flow, but we see how it is embedded in the situation of the preceding interactions, the tasks that are driving the discourse forward, the items in the whiteboard and other available resources (wiki postings by other teams, math knowledge, etc.). We had to conduct a preliminary analysis of the meaning-making process in terms of the interactional threading, the uptake of one posting by a subsequent one, the continuity of postings by individual participants, the subsidiary discussions to repair confusions, the references to various resources and the repeated citation of terms or phrases. Only then could we look more deeply into the interaction or investigate specific research questions.

If we wanted to classify individual chat postings according to some coding scheme in order to compare our excerpt to other interaction records, we would have had to do such a preliminary analysis to know what the brief, elliptical chat postings meant. CSCL is a human science and the analysis of its data requires an understanding of the meaning that things had for the participants. One cannot code a posting like “No!” as a mathematical proposal, a repair of understanding, an argumentative move or an off-topic comment without having a sense of the meaning of what the participants were doing linguistically and interactionally. Of course, if a chat posting just says, “Hi,” then even a simple algorithm can code it as Greeting, Social or Off-Topic with high reliability. However, we have found that the most interesting interactions are challenging for experienced researchers and likely to inspire divergent but productive analyses.

So far our analysis of the excerpt is quite preliminary. There is still a lot of ambiguity about what is going on. Line 1396/1399 remains quite intriguing: “We got the solutions. But I’m not sure how to explain how we got to the solutions, although it makes perfect sense to me.” If the solutions make perfect sense to Aznx, why does he feel that he cannot explain how they got the solutions? As noted above, this points to a fundamental problem in mathematics education. Students are trained to compute solutions, but they have difficulty articulating explanations. Some educational theories point to explanation as the core of “deep understanding” (Moss & Beatty, 2006).

Proponents of collaborative learning point to the importance of opportunities to explain math thinking to others as being important even for the development of one's own higher-order learning skills (Wegerif, 2006).

We may still wonder what the significance is of the fact that Aznx seems ready to post an explanation at line 1421 despite his repeated disclaimer at line 1401. Does line 1421 signal that the ensuing interaction is being taken as an adequate account or is the fact that things made perfect sense to Aznx now taken as adequate although it was not previously? Aznx does say in line 1403 that he can explain "the second formula." Does this entail that all that is needed is such an explanation of the second formula? Note that Aznx's line 1421 says, "So we're technically done with all of it, right?" What does the "So" respond to as an uptake? What has suddenly made the group ready to post an explanation? This line follows the extended effort to overcome the confusion of referencing, and it is hard to trace the "So" back to some clear point that it is building on. Furthermore, what is the significance of the hedge, "technically"? In fact it is not even clear what "it" refers to. Is Aznx just saying they are done with the repair, rather than with the whole explanation? Line 1423/1425 with its "all right" response seems to take line 1421 as saying that the group is ready to post their solution. It then proceeds to propose the logical next step, "let's put it on the wiki…. And let's clearly explain it." Aznx no longer resists, but in line 1426 he proposes that Bwang do the posting. In previous sessions, Aznx has requested that Bwang do the wiki postings, using precisely the same wording. Bwang has done previous wiki postings for the group. In this way, Aznx' statements leave ambiguous whether or not he still expresses doubt about his ability to explain the group's solution path and the extent to which he indicates understanding that path.

It not only remains ambiguous how much Aznx can explain, but also what exactly he was referring to as "the second formula." The repair of confusion shifted from distinguishing the second from the third formula to distinguishing Team C's formula from Team B's. Quicksilver and Aznx clearly pointed to two different text boxes in the whiteboard containing formulae as "ours" and "theirs." But the text box called "ours" contained three formulae: for the big square, for the 4 corners and for the diamond pattern as the difference. Did Aznx originally mean that he could only explain the second of these three—which was based on the formula for triangle numbers? Did Quicksilver's mention of triangle numbers in line 1402 and more general review of their solution path help Aznx to feel that they could put together an explanation of how all the formulae fit together? The discourse in this excerpt does not seem to provide complete answers to some of these questions. While careful analysis of small group discourse often reveals much about the problem-solving work of the group and its members, many other issues remain ambiguous, missing and even contradictory. The group did its work without resolving or explicating all of the issues that researchers may want to know about.

Methods of intersubjective meaning making

We have seen that an understanding of the intersubjective meaning-making process of a small group in a text-chat environment involves paying attention to an intricate web of connections among the items in the interaction record and items from the context that are made relevant in the discourse. There is a *threading* of the flow, with a particular posting following up on a preceding one (that may not be immediately adjacent in the chat log) and opening the possibility of certain kinds of postings to follow. There is *up-take* of one phrase or action by another, carrying the work of the group ahead. There are often important *continuities* from one posting of a particular individual to the same person's subsequent postings. Various sorts of communication problems can arise—from typos to confusion—and *repairs* can be initiated to overcome the problems. Lines of chat can *reference* items outside the chat, such as whiteboard drawings, formulae learned in the past or notions raised earlier. Terms and phrases in a posting can serve as *citations* of previous statements, making the former meanings once more present and relevant. One could easily draw arrows on a record of the chat excerpt to indicate several dozen of these connections of threading, uptake, continuity, repair, reference and citation. The postings can be separated into columns by poster to reflect continuity (see Stahl, 2006d, p. 100), and a column added for referenced items external to the immediate discourse. The intricate web of arrows would indicate how interwoven the postings are and how the postings of the different participants are tied together, creating an overall flow to the group discourse. *The meaning of the interaction is co-constructed through the building of this web of contributions and consists in the implicit network of references*. The point is not to reify this network as the answer to the question, *what* is meaning, but to see it as a way of understanding *how* meaning is co-constructed, i.e., how people *make sense* together.

There are many methods that members of a group, community-of-practice or culture employ to accomplish meaning-making moves in small-group interactions. In face-to-face interactions, certain typical "adjacency pairs" (like question/answer or greeting/response) form common "member methods" (Garfinkel, 1967). In chat, the two postings that belong to an adjacency pair may not be directly adjacent, but they retain the basic structure of forming a meaningful interaction through their combination. In looking at collaborative problem-solving extracts in VMT logs, I defined a typical pattern of "math-proposal adjacency pairs" (Stahl, 2006d). Here, one participant proposes an approach for the group to take to a problem or current sub-problem and someone else must either accept or decline the proposal on behalf of the group. If it is declined, then some kind of argument or alternative proposal is expected. If the proposal is accepted, then the group can continue working on the proposal, often by considering a follow-up proposal pair. There are a number of conditions that must be met by a proposal for it to be successful. These involve its timing and relevance in the flow of the discourse. A bid at a proposal that does not satisfy these conditions is likely to fail to be taken up as a proposal. The bid/acceptance pair may be temporarily interrupted by clarification questions or repairs to the bid's formulation. These, in turn, can lead to discussions of indeterminate length. Math proposal adjacency pairs provide a social order for discussions of mathematical problems in small groups. In the excerpt of Table 1, the students are no longer solving a math problem, but reflecting on their solution, trying to recall the steps that they went through and to explain how they solved it in a way that will be meaningful for an audience of their peers (the other teams who read the wiki) and their facilitators (who provide feedback and judge the winning teams). Here, there is a similar process of making proposals and responding to them, but the proposals are formulated more as declarative statements that recall past actions and the responses are rather oblique. In addition, Quicksilver and Aznx tend to continue their presentations in multiple postings, creating parallel threads. While there is an underlying social order that makes this excerpt meaningful, as we have seen it takes some analysis to uncover this order.

Even in this brief excerpt, we have seen many member methods or social practices that the participants use to co-construct meaning. Mostly, they respond to each other, making suggestions and posing questions. In addition, they work on repairing problems, such as the confusion about references to formulae. In resolving the confusion, they called upon the referencing tool in the VMT environment. This was the equivalent for the online context of pointing with a physical gesture when face-to-face. Different media provide different affordances and impose different constraints. In new media like this specific chat environment, participants have to be creative in adapting traditional meaning-making methods or inventing new ones. Students may be very inventive and this may impose extra effort on analysts who want to study the meaning-making processes and practices in innovative settings.

The foregoing analysis of meaning making in the excerpt is purely preliminary. A fuller analysis would depend upon one's research interests and specific questions. The excerpt would have to be understood within its larger context, including: the four full sessions, which are being reflected on here; the feedback from the facilitators, as it developed in response to the different sessions and based on the original task instructions; the various postings to the whiteboard and to the wiki; and even some of the work of the other teams. But perhaps this preliminary analysis is enough to indicate some of the methods of meaning making that take place in CSCL settings like the VMT sessions. There are phenomena observable at many granularities of analysis. The interactions among brief sequences of postings such as those in Table 1 may be considered the cell-form or elements of the meaning making that underlies computer-supported collaborative learning.

Preconditions for cognitive processes by groups

Now that we have a general sense of how meaning making takes place in CSCL (its *conditions*), what are the implications for design? What do we need to consider when attempting to support effective meaning making in CSCL? One approach to this question is to consider the logical and practical *preconditions* for students to get together and engage in joint meaning making to accomplish group cognitive tasks. In philosophical terms, this is to specify the preconditions for the possibility of group cognition. Based on our empirical experiences in the VMT project, here is a tentative list of some necessary—though not sufficient—preconditions for small groups of students to collaborate on math problems and other high-order cognitive tasks. The particular number, order and description of these preconditions is, of course, open to debate, extension and refinement. Nevertheless, it may be helpful to consider them when organizing CSCL environments and activities. Here are some preconditions (with examples from the analyzed excerpt):

1. *Intersubjectivity*. Participants must be willing and able to interact with others as peers. They must recognize others as active subjects with their own agency and be willing to relate to them as such. (human sociability)
2. *Opening of interaction space*. There must be a "world" in which people can come together and interact. The world must provide a network of meanings and possibilities for action. This situation defines deictic (Hanks, 1992), semiotic and semantic relations. (a virtual world, such as those created in the VMT project)
3. *Object of activity*. There must be a reason for interacting, a goal to work for, a topic to discuss, a problem to solve or an outcome to reach. (the math topic and motivating context)

4. *Shared intentionality*. It must be possible for participants to orient in common to objects, to focus their comments and activities on the same items, to "be-there-together" at a topic of joint concern, to "construct and maintain a shared conception of a problem." (e.g., the students' focus on the same formulae and tasks)
5. *Historical interpretive horizon*. Meanings of artifacts, words, domain concepts, etc. evolve through history and local pasts. Participants must have lived histories that overlap enough to share understandings of historically evolved meanings. (the term "triangular numbers" brought in from classroom background experience)
6. *Shared background culture*. Participants must share a language, a set of member methods, a vast tacit background knowledge of domain information and of ways of being human. (including how to "do" math)
7. *Member methods for social order*. Participants inherit and are socialized into an endless variety of member methods for conducting interaction and creating social order. However, small groups must also constantly adapt and enact methods to meet unique situations and innovative technologies. New methods must be fluidly negotiated and adopted for shared use *in situ*. (such as pointing from a chat message)
8. *Designed affordances of infrastructure*. The technological features of a CSCL medium define many features of the world which is opened up for interaction. These features are enacted by the participants to provide affordances for their activities. The enacted affordances are often quite different from the features imagined by the designers and can only be discovered through analysis of actual usage. (e.g., the pointing tool)
9. *Dialogic inter-animation of perspectives*. A key source of creativity, meaning making, problem-solving vitality—but also ambiguity—is the interaction of participants with essentially different interpretive perspectives (Wegerif, 2006). The power of CSCL is largely dependent upon its ability to bring different perspectives together effectively. (Bwang's math skills, Aznx' questioning, Quicksilver's recall)
10. *Creation & interpretation of group meaning*. The meaning-making process discussed in this paper lies at the core of computer-supported collaborative learning. It must be supported by CSCL environments. (pointing)
11. *Group-regulation & group meta-cognition*. Small groups of learners working on wicked problems that have no fixed solution path must have methods for proposing, negotiating, discussing, adopting and reflecting upon their path of inquiry. Methods of explaining their work are part of this. Scripting and other forms of scaffolding may help groups develop skills of self-regulation. (feedback about reflection on what to post to the wiki)
12. *Individual learning & interpretation*. The establishment of shared group meanings takes place through interactive processes like those we have noticed in this paper, involving the contribution of proposal bids by individual participants and the interpretation of meanings from individual perspectives (Stahl, 2006b, Ch. 16). Individual learning may result indirectly from the group cognitive processes that establish understanding by all participants. (the wiki posting done by Bwang later)
13. *Motivation and engagement*. Small groups and communities-of-practice determine their own interests and involvements through the particulars of what they work on and how they approach it. Individuals tend to become caught up in the group process through their contributions and participations in the interactions. Small-group processes appeal to the social inclinations of people, although they can also engender fears and pressures. In groups of several participants, the interactions can become quite complex, and engagement by different individuals in different activities may ebb and flow. (Bwang kept quiet, but entered strategically)

This paper has identified several interaction methods and group-cognitive processes that contribute to meaning making in CSCL settings. The interactions that constitute shared meaning are the elements of collaborative learning—as the co-construction of shared understanding, which includes individual interpretation. A number of preconditions for such interaction have also been proposed. An understanding of the conditions and preconditions of the small-group meaning-making process may aid in the design and analysis of CSCL activities.

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Acknowledgments

The ideas in this paper are indebted to many sources, most directly to the team of the VMT project at the Math Forum and Drexel. Detailed documentation of the VMT session: mathforum.org/wiki/VMT?VMTGroupB. The idea of preconditions of possibility for interaction was suggested by Rupert Wegerif in a discussion at Intermedia in Oslo. The theoretical and methodological focus on joint meaning making has prospered through interactions with Tim Koschmann and Dan Suthers, most recently in workshops at Freiburg and Tübingen. The research reported here was supported in part by grants to the author from the NSF programs for digital library services (NSDL), innovative technologies (ITR/IERI) and the science of learning (SLC).

Collaborative Argumentation and Cognitive Processing - An Empirical Study in a Computer-Supported Collaborative Learning Environment

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Abstract: It has been assumed that deep cognitive processing is associated with better understanding. Better understanding of the content is supposed to improve the quality of argumentation in the discussions. Although plausible, empirical tests of these assumptions are sparse. Therefore, the goals of this study are to examine these assumptions and to provide analyses of cognitive processes during collaboration. A one-factorial design with forty-eight (48) participants was used to investigate the relation between the formal quality of single arguments (low vs. high) during online discussions of groups of three, cognitive processes, and knowledge acquisition. The formal quality of single arguments was fostered by means of a computer-supported collaboration script. Empirical evidence was found that the quality of argumentative knowledge construction during discussion is positively related to deep cognitive processing and that the scripted construction of single arguments had a positive effect on the individual acquisition of knowledge on argumentation.

Collaborative Argumentation in Asynchronous Online Discussions

Several studies in the field of Computer-Supported Collaborative Learning aim to foster the quality of argumentation in discussions of learners in order to enhance individual knowledge acquisition (e.g., Andriessen et al., 2003; Jermann & Dillenbourg, 2003; Kollar et al., 2005; Kuhn & Goh, 2005). These approaches assume that explicit, high-quality argumentation is related to better cognitive processing and thus, to knowledge acquisition of the individual learner (e.g., Baker, 2003; Kuhn et al., 1997). Although plausible, empirical evidence for this set of interconnected claims is very rare. Therefore, this contribution aims to investigate the relations between the quality of argumentation in online discussions, cognitive processing, and knowledge acquisition.

Asynchronous online discussions have been considered as an appropriate context for learners to engage in high-quality argumentation and deep cognitive processing (Kuhn & Goh, 2005; Marttunen & Laurinen, 2001). However, learners rarely use this advantage of asynchronous communication (e.g., Marttunen et al., in press). An instructional approach aiming to support the processes of argumentative knowledge construction is based on computer-supported collaboration scripts. Collaboration scripts specify and sequence learning activities and assign roles to different learners (Kollar et al., 2006). Thereby they can facilitate specific discourse activities such as the construction of arguments. In this paper we examine the assumptions of argumentative knowledge construction about the relations between the quality of argumentation, the depth of cognitive processing, and knowledge acquisition. We therefore assess both the individual cognitive processes and the quality of argumentation in online discussion, which is fostered (and thereby experimentally manipulated) by means of an argumentative computer-supported collaboration script.

Argumentative Knowledge Construction

By "argumentative knowledge construction" we refer to the joint construction and the individual acquisition of knowledge through collaborative argumentation (cf. Andriessen et al., 2003). Argumentative dialogue that may foster argumentative knowledge construction is likely to occur in collaborative learning when two or more individuals try to find a solution for an authentic problem (e.g., de Grave et al., 2001). Some studies report substantial relations between argumentative structures in learners' discourse and individual knowledge acquisition (Baker, 2003; Chinn et al., 2000; Kuhn et al., 1997; Leitão, 2000).

The *construction of single arguments* can be described against the background of Toulmin's (1958) model of argumentation. In a simplified version of Toulmin's model, arguments may comprise the components claim, grounds, and qualifications. The *claim* is an expression of the position that is advanced in the argument. Under the term *grounds* we subsume the elements *data*, *warrant*, and *backing* from Toulmin's model. A *datum* is constituted by factual information that favors the acceptance of the claim. A *warrant* is a rule of inference that justifies the transition from the datum to the claim and reveals the relevance of the data for the claim, such as theoretical laws or definitions. A *backing* is factual information such as statistics or expert opinions that provides a rationale for a warrant. Like the supporting elements of Toulmin's model, also Toulmin's qualifier and its associated rebuttal can be conflated. We suggest the heading *qualifications* for these elements. The so-called *qualifier* marks limited certainty of the claim and is usually constituted by a modal adverb such as "perhaps" or "probably". The qualifier is directly dependent on the so-called *rebuttal* that specifies states of affairs that would weaken or invalidate the claim. According to our simplified model, a completely explicit argument would comprise a claim supported by grounds and limited by qualifications. Hence, the formal quality of single arguments can be described on the basis of this simplified model.

The explicit formulation of grounds such as data and warrant (Baker, 2003) and the explicit consideration of alternative viewpoints (Spiro & Jehng, 1990) are regarded as being related to deep cognitive processes that foster knowledge construction. In addition, the participation includes active reception of arguments, too. The confrontation with new ideas or different positions might challenge the own position. Completely explicit arguments could facilitate the evaluation of grounds and qualifications, while bare claims may rather hinder deep cognitive processing. Hence, deep cognitive processing could be related to both by the production and the reception of high-quality arguments. A crucial type of cognitive processing with regard to knowledge construction is *cognitive elaboration* (McNamara et al., 1996). Cognitive elaboration is the enrichment of learning material using additional information taken from or inferred in combination with prior knowledge. Hence, arguments of high formal quality with respect to argumentative knowledge construction should be associated with deeper cognitive elaboration. There is ample evidence that deep cognitive elaboration of the learning material is causally related to knowledge acquisition (e.g., Stein & Bransford, 1979). In problem-oriented learning environments, argumentative knowledge construction is supposed to foster, in the first place, the ability to use theoretical concepts and their interrelations to analyze and solve complex problems (Bransford et al., 1989), i.e., application-oriented, domain-specific knowledge. Additionally, there is empirical evidence that participation in high-quality argumentative discussions may foster the acquisition of knowledge on argumentation (cf. Kuhn, 1991). This comprises knowledge of the components of arguments described above and on how to construct arguments that consist of the components claim, grounds and qualifications (i.e., knowledge on the construction of single arguments). For these kinds of knowledge acquisition to occur it is regarded as crucial that the argumentation in the discourse among the learners is of high-quality. It has been demonstrated that computer-supported collaboration scripts can facilitate specific processes such as the ones that are assumed to be related to knowledge acquisition in argumentative knowledge construction (e.g., Weinberger et al., 2005a).

Effects of Computer-Supported Collaboration Scripts on Argumentative Knowledge Construction

The approach of *computer-supported collaboration scripts* to support online discussions took its inspiration from scripted cooperation (see O'Donnell, 1999, for an overview). Collaboration scripts are instructional plans that specify and sequence individual and collaborative learning activities that are associated with deeper cognitive processing and thereby facilitate knowledge acquisition. The various activities may also be assigned to different learners who then take different roles (Palincsar & Brown, 1984; for an overview see Kollar et al., 2006). Computer-supported asynchronous online discussions provide two important opportunities for the application of collaboration scripts. First, in asynchronous settings they provide learners with the opportunity to perform the activities required by the script at their individual pace. Second, in computer supported collaborative learning scripts can easily be implemented in the graphical user-interface of the collaboration tool (e.g. Baker & Lund, 1997; Hron et al., 1997). Learners do not need to split their attention between what they discuss (e.g. a case analysis) and the instructions about which activities they are supposed to perform (e.g. to construct arguments containing grounds). Therefore, computer-supported collaboration scripts are typically implemented as prompts (e.g. Weinberger, 2003), buttons (e.g. Hron et al., 1997), or input text fields (Kollar et al., 2005).

Weinberger et al. (2005b) designed a computer-supported collaboration script for argumentative knowledge construction in problem-based learning in a higher education setting. It was designed to improve the quality of single arguments in online discussions by providing a set of text windows and related prompts for the different components of a completely explicit argument, i.e., an argument consisting of a claim, grounds and qualifications. In an empirical study, Weinberger et al. (2005b) found evidence that the script fostered both the quality of argumentation in online discussions and the individual acquisition of knowledge about argumentation. The individual acquisition of domain-specific knowledge (on Weiner's attribution theory in this case) was not affected. The authors explained this pattern of findings by learners' limited cognitive resources: The time to acquire both knowledge on argumentation and domain-specific knowledge was restricted to 80 minutes in this experimental study. This required the learners to allocate a considerable part of their cognitive capacity to the construction of knowledge on argumentation and accordingly left little resources for enhanced domain-specific knowledge acquisition. Thus, the study showed that argumentative computer-supported collaboration scripts are feasible means to foster the quality of argumentation in online discussions as well as the acquisition of knowledge on argumentation, while at the same time it did not appear to impede domain-specific knowledge acquisition. Hence, this setting seems suitable to examine to what extent the quality of argumentation is positively related to deep cognitive processing. The study presented here can be regarded as a follow up to the study by Weinberger et al. (2005). This paper aims to examine the relation between high quality argumentative discussions and the depth of cognitive processing more closely.

Research Questions

The following research questions were examined:

(1) To what extent does the scripted construction of single arguments affect the quality of argumentation and the depth of cognitive elaboration during argumentative knowledge construction? In line with the study of Weinberger et al. (2005b) we expect that the scripted construction of single arguments has a positive effect on the formal quality of single arguments. Moreover, we expect that learners supported by the scripted construction of single arguments engage in deeper cognitive elaboration than learners without support of the script.

(2) To what extent is the quality of argumentation related to the depth of cognitive elaboration? We expect a positive relation between the formal quality of the learning partners' argumentation and the depth of cognitive elaboration and that the effect of the scripted construction of single arguments on the depth of cognitive elaboration is mediated by the formal quality of the learning partners' argumentation. Furthermore, we expect a positive relation between the depth of cognitive elaboration and the formal quality of the learner's argumentation as well as that the effect of the scripted construction of single arguments on the quality of the learner's own argumentation is mediated by the depth of his or her cognitive elaboration.

(3) To what extent does scripted construction of arguments foster the acquisition of domain-specific knowledge and knowledge on argumentation? Since we did not change the conditions of the experimental setting in comparison to the study of Weinberger et al. (2005b), we expect that the scripted construction of single arguments should have a positive effect on the acquisition of knowledge on the construction of single arguments and no further effects on domain-specific knowledge acquisition.

Method

Participants, Design, Unit of Analysis, and Statistical Tests

Forty-eight (48) students of Educational Science at the University of Munich participated in this study during the winter term 2003/2004. The mean age of the participants was M = 22.77 (SD = 3.66) years. Participation was a requirement for receiving course credit in a mandatory introductory course for freshman because the experimental learning environment was part of the regular curriculum. The experimental session covered an important theory (Weiner's attribution theory; Weiner, 1985) and was a substitute for a three-hour lecture in the course. The learning outcomes of the experimental session, however, were not considered in grading. We manipulated the variable "scripted construction of single arguments" (with vs. without) by means of a computer-supported collaboration script for the construction of single arguments that will be described below. The participants were randomly assigned to groups of three. The groups were then randomly assigned to one of the two experimental conditions in this one-factorial design.

We decided to take the individual learners as the unit of analysis because individual knowledge acquisition is a main point of interest in this study and assumed to be a consequence of individual cognitive processes. However, learners in a group of three cannot be regarded as mutually independent, which can be considered as a violation of the random sample prerequisite of statistical procedures. Hence, we randomly selected one learner per group for this analysis, i.e. in the analysis each of the 16 groups is represented by one of its members.

Material and the Collaborative Learning Task

The content of the learning environment was Weiner's attribution theory (1985) and its application in education. In an educational context, this theory can be used to explain the learning motivation of people on the basis of the kinds of causes to which they themselves attribute success or failure. The students read a three-page description of this theory.

Three learning cases about practical contexts were used as a basis for online discussions in the collaborative learning phase. Each case was close to reality, complex and allowed learners to construct different arguments based on attribution theory. The group's task was to analyze the three cases and to come up with a joint solution for each case. The three students in each group were distributed over three laboratory rooms. An asynchronous, text-based discussion board was used for collaboration. This discussion board allowed the exchange of text messages that resembled emails. Learners could either start a new topic by posting a new message or reply to messages that had been posted before. Each message consisted of a subject line, author information, date, time, and the message body. While the learning environment set author information, date, and time automatically, the learners had to enter the subject line and the body of the message. Each of the three cases was discussed on a separate discussion board, and learners could switch between these boards at any time during the collaborative learning phase.

Implementation of the Scripted Construction of Single Arguments

The environment allowed for the graphical implementation of different types of computer-supported collaboration scripts. (1) The *control group* received no additional support in solving the three problem cases. (2) The *scripted construction of arguments* was implemented in the CSCL interface as a graphical structure of input text boxes that should help learners to construct single arguments (see Figure 3). The script, based on our simplified version of Toulmin's model (1958), differentiates between claim, grounds and qualifications. The learners were asked to fill in each text box of the interface to construct a completely explicit argument. After constructing the argument, they could add the argument to the message body by clicking on a command button ("add" button; see Figure 1). This triggered the event that the graphical structure was translated by the system into a pre-specified textual structure for the individual messages. Then, the learners could either construct a new argument with support from the graphical structure or submit the message. Non-argumentative parts of the message, such as questions, comments or expressions of emotion could be inserted directly into the message body, without using the argument construction script.

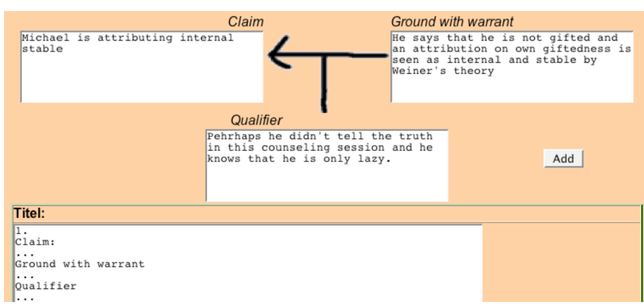

Figure 1. The interface of the script for the construction of arguments. This extension was placed between the description of the cases and the regular user interface. It comprises input text fields for claim, grounds and qualifications. With a click on the add-button, the argument was pasted to the input text field of the regular interface and the input text fields of the extension were cleared.

Procedure

First, the participants completed pretests that were designed to measure domain-specific prior knowledge and prior knowledge on argumentation. The data from these tests were used to control randomization. Subsequently, the participants had 20 minutes to read the three-page description of attribution theory individually. After that, the learners were introduced to the learning environment and to the think-aloud procedure. Then they collaborated for 80 minutes in groups of three, trying to develop solutions for the three cases and to reach agreement about them. In the final phase (about 45 minutes), the students took individual posttests on domain-specific knowledge and knowledge on argumentation. Time on task was held constant for the two conditions.

Data Sources and Variables

Quality of the construction of arguments. To assess the construction of arguments, the students' written online discussions during the collaborative learning phase were analyzed by means of a segmentation and coding procedure developed by Weinberger and Fischer (2006). Only the messages that referred to the case "Math" (about 1200 segments counted across all groups) were included in the analysis.

The discourse corpora were segmented by trained coders. The segmentation was based on propositional units, i.e. the criterion for segmentation was to separate units that include concepts from attribution theory that could be evaluated as true or false. E.g., the sentence "Michael is attributing internal and stable." was segmented into "Michael attributes internal" and "[Michael attributes] stable". With respect to the segmentation of the discourse corpora, the coders achieved an agreement of 84% during the training.

The segmented discussions were then analyzed for the construction of single arguments. With respect to the construction of arguments, the coders had to distinguish between (1) bare claims, (2) supported claims, (3) limited claims, and (4) supported and limited claims. Bare claims are neither explicitly supported by grounds, nor explicitly limited in their claimed validity by qualifications, e.g. "Michael attributes as internal". Supported claims are assertions for which grounds are provided. In the context of this study, learners could support their claims with grounds that were either observations from the case description (data) or definitions, laws and findings from research on attribution theory (warrants and backings), for example. Indicators for grounds that support claims are conjunctions such as "because", "due to the fact that" etc., yet learners do not always explicitly connect reasons to the corresponding claims. For instance, the claim "Michael attributes as internal" may be supported by the grounds "Michael ascribes his failure to lack of talent." and "Ascribing failure to lack of talent is an internal attribution". Limited claims are restricted in their claimed validity by qualifications, e.g. "[...] provided that Michael tells the truth". Supported and limited claims are both accompanied by grounds and restricted by qualifications. Five trained coders coded the online discussion. About 5% percent of the discourse data presented in this study were coded by all five coders. The interrater agreement computed on the basis of these overlapping codings of the construction of single arguments was sufficiently high (median of Cohen's $\kappa = .70$).

The *quality of the construction of arguments of the individual learner* is a compound variable that was defined as the amount of written arguments of one learner during the online discussions that were either supported by grounds or limited by qualifications, or both in the argumentation of the learner. The *quality of the construction of arguments of the learning partners* was determined in analogy to the previous variable, but only on the basis on the contributions of each learner's two partners, i.e. as the amount of arguments of the learning partners with grounds and/or qualifications.

Depth of cognitive elaboration. The participants were asked to think aloud during the whole collaboration phase. They were advised to articulate their thoughts without explaining or commenting on them. In each laboratory room, an experimenter was seated together with the participant in order to ensure that the think-aloud procedure was performed correctly. If necessary, the experimenter used one of the following sentences to advise the participant: "Please keep on speaking!", "Please do not comment your thoughts!", or "Please do not explain your thoughts!" The think-aloud protocols were recorded by the computer using a software that captures both the content of the computer screen and the audio signals from the laboratory room simultaneously. The think-aloud protocols were broken down into segments of ten seconds of duration. Trained coders classified each segment of the think-aloud protocols. "Cognitive elaboration" was coded when learners elaborated propositional units in which they applied concepts from attribution theory. Note that these propositional units were not provided in the learning material, but had to be inferred by the learner. Experts identified the propositional units that referred the case "Math", e.g., "Michael is attributing as internal", "The teacher is attributing as internal", or "The parents are attributing on missing ability". The median of the agreement between the coders concerning the categorization was sufficiently high (Cohen's $\kappa = .78$).

Following a line of argumentation introduced by Craik (2002), we operationalized the depth of cognitive elaboration as the duration of cognitive elaboration per proposition. According to Craik, the duration of cognitive processes can, under certain circumstances, be interpreted as an indicator of the depth of cognitive processing. The depth of cognitive elaboration depends on several attributes of learners, learning material, and the learning task. For example, learners with a high level of relevant prior knowledge process information faster than learners with a low level of knowledge. Different learning content (e.g., reading a novel vs. reading a manual) requires a different processing time. Memorization takes an amount of time different from problem solving. Therefore, there cannot be a general objective index of depth of cognitive elaboration. Conversely, however, this means that the duration of cognitive elaboration by similar learners with similar prior knowledge who process the same information with respect to the same task may allow for intersubjective comparisons of the depth of cognitive processing. Hence, all learners received the same learning material with the same task, and only freshmen were examined. The comparability of their prior knowledge was tested (see section "Randomization check").

Tests of domain-specific knowledge. Both the pretest and the posttest for the measurement of domain-specific knowledge consisted of the task to analyze a problem case from a practical context. The participants had to write an analysis based on Weiner's (1985) attribution theory individually on a sheet of paper and received no additional support. The case "Choosing a major" was used for the pretest and is about the influence of parents on their daughter's choice of her major subject at the university. In the case "Text analysis", which was used for the posttest, a student talks about the reasons of failing an exam in text analysis. Individual pretest and posttest were analyzed by means of a segmentation (see above for segmentation rules) and coding procedure developed by Weinberger (2003):

For the *pretest* experts identified propositional units in which theoretical concepts from attribution theory are used to describe case information concerning the case "Choosing a major". The number of these propositional units in the pretest was used as an indicator for domain-specific prior knowledge. Due to a floor effect (most participants did not apply concepts from attribution theory in the pretest), the reliability of the measurement was rather low (Guttmann split-half, $r = .42$).

For the *posttest*, experts identified propositional units in which theoretical concepts from attribution theory are used to describe case information concerning the case "Text analysis". The number of different propositional units that could be identified in a subject's analysis of the posttest case was used as a measure for his or her domain-specific knowledge. The reliability was sufficient (Guttman split-half, $r = .62$).

Tests of knowledge on the construction of arguments. In the *pretest*, prior knowledge on the construction of arguments was operationalized as the amount of arguments in the individual analysis of the problem case that were either supported or limited, or both, according to the segmentation and coding procedure that was described above for the analysis of the students' discussions.

In the *posttest* of knowledge on the construction of single arguments the participants were asked to recall components of single arguments (claim, grounds, and qualifications). For the successful recall of each of the three components they were credited one point. In addition, the participants were asked to formulate completely explicit arguments about "smoking" that contained all of the components of the simplified Toulmin model. These arguments were analyzed with respect to the components of a single arguments (claim, grounds, and qualifications). For each of the three types of components that were appropriately contained in the students' responses they were credited one point. Hence, the test scores could range from 0 to 6 points. Two trained coders rated the knowledge on argumentation tests (Cohen's $\kappa = .83$). The reliability coefficient was sufficiently high (Guttman split-half, $r = .88$).

Results

Randomization Check

In order to control potential effects of interfering variables and to ensure that randomization was successful, we compared a) the experimental conditions and b) unselected vs. selected individuals from the small groups with respect to domain-specific prior knowledge and prior knowledge on argumentation. These tests were conducted on a 20 percent alpha-level to reduce the probability of type-II-errors. Because of the floor effect of domain-specific prior knowledge, a Chi-square test was conducted with regard to this variable as well. Neither between the experimental groups nor between selected vs. unselected individuals significant differences were found.

RQ1: Effects of the Scripted Construction of Single Arguments on the Formal Quality of Single Arguments and the Depth of Cognitive Elaboration during Argumentative Knowledge Construction

The effects of the scripted construction of single arguments on the quality of the construction of single arguments and the depth of cognitive elaboration of the learning material were tested.In the scripted construction of single arguments condition learners produce more then twice the amount of supported claims (M=11.88, SD=7.08) than learners in the control group (M=5.38, SD=5.76), i.e. the script increases the *quality of construction of arguments* substantially ($t_{(14)}$ = -2.02, p < .05, d = 1.01, one-tailed). This finding replicates the findings of Weinberger et al. (2005) and supports our expectations. The scripted construction of single arguments also increased the *depth of cognitive elaboration(M=31.51, SD=16.68)* in comparison to no support by the script (M=62.67, SD=38.89). This effect was significant and large ($t_{(14)}$ = -2.05, p < .05, d = 1.04, one-tailed). This result is in line with our expectations and the assumptions concerning argumentative knowledge construction.

RQ2: Relation between the Formal Quality of Single Arguments and the Depth of Cognitive Elaboration

With regard to RQ2 we examined two relations: The first is the relation between the depth of their cognitive elaboration of the learning material and the quality of the learners' own single arguments in online discussion. The second is the relation between the quality of the single arguments of the learning partners and the depth of the learners' cognitive elaboration of the learning material.

As expected, the depth of the cognitive elaboration of the learning material is positively correlated with the quality of a learner's single arguments in the online discussion, i.e. the deeper the cognitive elaboration of the learning material, the higher the formal quality of single arguments of the learner. This correlation is large and significant (r = .64, N = 16, p < .05, one-tailed). A positive correlation that was not significant was found between the formal quality of the single arguments of the learning partners and the depth of the individual learners' cognitive elaboration (r = .44, N = 16, *n.s.*, one-tailed).

Additionally, we conducted two mediator analyses. If the variable examined actually mediates the effect of the scripted construction of single arguments, no effect on the residuals or an effect with a considerable smaller effect size (i.e. at least a one third lower than the effect on the criterion itself) should be found (cf. Baron & Kenny, 1986). We tested the depth of the learners' cognitive elaboration of the learning material as a predictor of the quality of their own single arguments in online discussion and the quality of the single arguments of the learning partners as a predictor of the depth of the learners' cognitive elaboration of the learning material. The first regression analysis predicts the formal quality of the learners' own single arguments on the basis of the depth of the learners' cognitive elaboration and explains a large proportion of its variance (F(1,14) = 6.72, p < .05, $R^2_{adj.}$ = .31). No effect of the script on the residual was found ($t_{(14)}$ = -1.61, *n.s.*, one-tailed). Hence, the effect of the script on the formal quality of the learners' own single arguments was mediated by the depth of the learners' cognitive elaboration. As indicated by the correlation reported above, in the second regression analysis the quality of the single arguments of the learning partners was not a significant predictor of the depth of the learners' cognitive elaboration (F(1,14) = 2.81, *n.s.*, $R^2_{adj.}$ = .12). The scripted construction of single arguments still had a significant and strong effect on the residual from this regression model ($t_{(14)}$ = -2.17, p < .05, d = 1.16, one-tailed). The effect size of the effect of the scripted construction of single arguments on the residuals of the depth of the learners' cognitive elaboration was 11.50% percent higher than the effect size of the effect of the scripted construction of single arguments on the depth of the learners' cognitive elaboration (d = 1.04; see RQ1). Hence, the formal quality of the single arguments of the learning partners cannot be considered as a mediator of the effect of the scripted construction of single arguments on the depth of cognitive elaboration in this context.

RQ3: Effects of the Scripted Construction of Single Arguments on the Acquisition of Domain-Specific Knowledge and Knowledge on the Construction of Arguments

Effects on the acquisition of domain-specific knowledge. Though learners in the scripted construction of arguments condition used theoretical concepts to describe case information in the individual posttest more often (see Table 1), this difference was not significant ($t_{(14)}$ = -0.76, *n.s.*, one-tailed). This finding replicates the findings of Weinberger et al. (2005b) and is in line with our expectations.

Effects on the acquisition of knowledge on the construction of single arguments. With respect to knowledge on the construction of arguments, learners in the scripted construction of single arguments condition scored about 30% higher than learners without support of the script in the posttest (see Table 1). The scripted construction of arguments fosters the acquisition of knowledge on the construction of arguments significantly and substantially ($t_{(14)}$ = -5.29, p < .05, d = 2.63, one-tailed, see Table 1). This finding again replicates the findings of Weinberger et al. (2005b) and is in accordance with our expectations.

Table 1: Individual outcomes of argumentative knowledge construction by experimental condition: means (m) and standard deviations (SD).

		Control group	Script for the construction of single arguments
Domain-specific knowledge acquisition		4.00	5.75
	SD	2.07	3.49
Acquisition of knowledge on construction of single arguments		3.50	5.50
	SD	0.76	0.76

Conclusions

With regard to RQ1, we could replicate the finding of Weinberger et al. (2005b) that the quality of argumentation can be fostered during collaboration by means of a computer-supported collaboration script. We found evidence that the scripted construction of arguments affects the depth of cognitive elaboration of the learning material.

With respect to RQ2, we found evidence that the depth of a learner's cognitive elaboration of the learning material is positively related to the quality of his or her argumentation. The mediator analysis showed that the depth of cognitive elaboration mediated the effect of the scripted construction of arguments on the quality of argumentation. With regard to the relation between the cognitive elaboration and the quality of the other learners' argumentation in the discussion the relation was less close compared to the relation between the depth of a learner's cognitive elaboration of the learning material and the quality of the learner's own argumentation. Therefore, this evidence is rather inconclusive. The mediator analysis indicated that the effect of the scripted construction of arguments on depth of cognitive elaboration might not be mediated by the quality of the *other learners' argumentation* in the discussion.

With respect to RQ3, we were able to replicate a second finding of Weinberger et al. (2005b): The computer-supported scripted construction of arguments fostered the acquisition of knowledge on argumentation without affecting the acquisition of domain-specific knowledge.

The findings of this study provide support for crucial assumptions about argumentative knowledge construction: We found empirical evidence for the claim that high quality collaborative argumentation is associated with deeper cognitive processing (as assumed, e.g., by Baker, 2003) as well as with the acquisition of knowledge of the individuals participating in a discussion. The simultaneous increase of the quality of argumentation and the depth of cognitive processing by the use of the collaboration script and the mediator analysis make it plausible that deep cognitive elaboration precedes high-quality arguments. However, one reason for deep cognitive elaboration may be the requirement to formulate high-quality arguments with grounds and qualifications. Hence, the writing of arguments and the depth of cognitive elaboration might interact reciprocally in a more complex way than we are able to test here. The findings with respect to the relation between the quality of arguments of the learning partners and the depth of cognitive elaboration were more inconclusive. They cannot be taken as evidence that the contributions of the learning partner do not affect the depth of cognitive elaboration. We can only speculate that high-quality argumentation as well as low-quality argumentation of learning partners can provoke deep cognitive processing. It might rather depend on the difference between the position of the individual learner and the position of his or her learning partners. If a claim with grounds and qualification is in line with the learner's position, he or she might tend to not engaging in deep cognitive elaboration, while a claim that challenges the own position, regardless whether a bare one or one supported by grounds, may provoke deep cognitive elaboration. Accordingly, learners might be in need of support during the reception of arguments. Although this study cannot provide conclusive evidence on this issue due to the small sample size, the experimental time constraints etc., it might stimulate more systematic empirical research on the relevance of the learning partner in computer-supported collaborative argumentation. Such research can take studies on the interaction of text characteristics and learner characteristics as starting point (McNamara et al., 1996).

However, some limitations of the study and thus the validity of its findings should be noted as well. To zoom in on the discursive and cognitive mechanisms involved in learning through argumentation, we chose to restrict our setting with respect to collaboration time and degrees of freedom in participation in an experimental laboratory setting. Some of the results could possibly be attributed to these restrictions. For example, it is an open question, what effects a collaboration script might have on the acquisition of domain-specific knowledge, when longer periods of time are considered. Under such conditions, individuals would be less strictly forced to decide how to allocate cognitive resources under time pressure. Moreover, once the argumentative knowledge has been acquired, more cognitive resources would be available for the acquisition of domain-specific knowledge (see Kollar et al., 2005). Furthermore, when the learners are able to perform the scripted activities by themselves, the external support need no longer be present in the interface and should be faded. It is still unclear, when and how fading of collaboration support should take place (see Pea, 2004). A further limitation concerning the generalizability of the findings applies. The study focused on specific aspects of argumentation, namely the construction of single arguments. The effects of scripts addressing more dialectic aspects (e.g., the sequencing of arguments, counterarguments, and integration were not examined in this paper. Therefore, the conclusions with regard to the relation of collaborative argumentation and cognitive processing might be limited to a specific (though important) subfield of argumentation.

Methodologically, this study contributed to advance the field in showing the potentials of using the think-aloud method in collaborative settings. The use of this method provided data to exemplarily test a hypothesis inherent in many approaches to collaborative learning: The hypothesis that specific collaborative activities are associated with the cognitive processing of the information by the participating individuals (e.g., King, 1999). Note that the main results of this study replicate findings of another study without the think-aloud procedure (Weinberger et al., 2005b). This can be taken as evidence that the method did not substantially interfere in a systematic way with the collaborative knowledge construction activities under investigation.

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Acknowledgements

This research has been funded by the Deutsche Forschungsgemeinschaft (DFG).

Wearable Tag Clouds: Visualizations to Facilitate New Collaborations

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Abstract: We describe the development and pilot testing by university faculty of Wearable Tag Clouds as a CSCL technology. Tag Clouds are 'at-a-glance' information visualizations that, in the wearable form developed here, repurpose social web technologies to support face-to-face interactions. Exploration of collaborative prospects is facilitated by visualizing the substantive emphases of researchers' written works. Pilot test results suggest wearable information visualizations can positively impact face-to-face interactions in collaborative communities.

Introduction

It has been said that researchers in the field of computer-supported collaboration spend a lot of time at conferences but rarely use the ideas and technologies from their research to make this time more productive (Borovoy, 1998). Conferences are sites of face-to-face interaction for people with common interests and offer opportunities to forge new collaborations. Through interaction, participants *learn* about each other's interests and expertise, and *evaluate* potential collaborative opportunities. To echo (Borovoy, 1998): "[The] groundwork for meaningful and enduring collaborations can be laid at such events and…encouraged with appropriate technology."

This paper presents the design and pilot testing of a wearable information visualization to facilitate face-to-face interaction, learning about peers, and the formation of collaborative relationships. The Tag Cloud visualization technique, a common sight on the Web today, is here applied for the first time in a face-to-face community: to create personal, wearable visualizations of each participant's research interests and other relevant descriptors. A Wearable Tag Cloud looks like a traditional conference name-badge, though slightly larger to accommodate the wearer's personal visualization. After a brief introduction to Tag Clouds and the technology we've developed to produce them, we connect and compare this work to related research, report preliminary observations from the pilot user trial, then discuss what was learned and how it will inform future design and research iterations.

Figure 1. Tag Cloud worn by the first author at a Stanford faculty retreat.

What are Tag Clouds?

Tag Clouds came into popular use as web-based visualizations of the keywords (so-called "tags") assigned by users to describe and categorize user-contributed content online (Mathes, 2004). A typical Tag Cloud visualizes the relative frequency of the most common tags in use and doubles as an index for accessing content categorized by each tag. To date, academic research on Tag Clouds is almost non-existent, and what does exist focuses narrowly on their use as keyword visualizations and website navigation aids (Hassan-Montero, 2006).

This paper generalizes the definition of a Tag Cloud to be any list of words visually weighted by their relative frequencies in a source text. On the Web, the source is usually a database of keywords. In our work, we wished to visualize representative research texts like curriculum vitae, research statements and publications. To pursue this research, we have developed a web-based application (Steinbock, 2006), open to the public, to generate Tag Clouds from any source text (1). The application outputs Clouds in the canonical form (see Figure 1), an alphabetic list of words whose type sizes are proportional to their relative frequency in the source text (2).

Previous Work

Well-designed information visualizations enhance cognition (Card, 1999) just as the affordances of designed objects can enhance physical, perceptual and learning abilities (Norman, 1993; Gibson, 1966; Pea, 1993). The prototypical wearable display for personal information is the conventional nametag. The affordances it provides—that is, the ways of use it makes possible—are perfectly suited to its role in social situations. A nametag dispenses information where and when it is most useful and relevant: in plain sight, during face-to-face encounters.

Researchers have developed computationally-augmented nametags in an attempt to better support face-to-face interaction at conferences (Borovoy, 1998). The devices have also been used in the CSCL community for participatory simulations (Andrews, 2002). Known as Thinking Tags, these devices store information about the wearer (interests, beliefs) and then wirelessly communicate to compute a similarity score on a five-point scale when two people interact face-to-face. The resulting numeric measure is displayed on an array of LEDs.

As wearable displays that double as nametags, both Tag Clouds and Thinking Tags dispense personal information when it is useful and relevant—during face-to-face encounters—but they differ in a number of important ways. With regard to information affordances, Thinking Tags display simple, quantitative information in dynamic response to pair-wise interactions. This approach primarily serves the goal of evaluating collaborative potential and attempts to automate social matching (Terveen, 2005). But in addition to being expensive and technically complex, this high-tech approach is more automating than augmenting (Engelbart, 1963). Collaborative potential is algorithmically reduced to an evaluation based on a five-point scale, without establishing the substantive basis for common interest. In contrast, Wearable Tag Clouds are simple physical printouts of computer-generated visualizations that, in spite of being non-computational, are more information-rich.

Wearable Tag Clouds

This predecessor technology and the theory of affordances suggested that new visualization techniques could prove useful in a facilitative role for face-to-face interactions. Recognizing that the formation of collaborative relationships involves both *learning* about others to discover areas of shared interest and *evaluating* collaborative potential, Wearable Tag Clouds were designed to support both tasks by making substantive information relevant to both goals *mutually visible*: personalized visualizations of a researcher's persona, including research interests, expertise, frequent collaborators, institutional and geographic affiliations. The content of representative texts are used as input to our Tag Cloud engine (e.g. curriculum vitae and research statements) to produce a compact visual synopsis of the researcher's academic life—a ‘virtual concept badge’ for seeing interest patterns at a glance. The resulting artifacts act as conversational props, relying on visual perception and interactive conversation—rather than automation—to unpack the field of shared interest and evaluate collaborative opportunity. Two or more people learn about each other by examining one another’s Tag Clouds; they evaluate the collaborative potential by comparing their Clouds, and conversing with reference to them. The following section describes observations and analysis from the first pilot of Wearable Tag Clouds, leading into final design considerations for future iterations.

Pilot User Trial

Wearable Tag Clouds were piloted for the first time at a faculty planning retreat for the new interdisciplinary H-STAR Institute (Human Sciences and Technologies Advanced Research) at Stanford University. This retreat gathered together twenty-five faculty members from a wide diversity of disciplines (Linguistics, Computer Science, Philosophy, Psychology, Mathematics, Education, and others). The participants—most of whom were not previously acquainted with those outside their own department—gathered at the retreat for the purpose of introductions and learning about each other’s work, culminating in the identification of emergent, multi-faculty, cross-department research themes, and the initiation of collaborative research white papers to serve as the foundation for an H-STAR strategic research plan.

Personal Tag Clouds were created for each faculty participant using curriculum vitae as the primary input, supplemented with research statements, where available. Figure 1 shows the first author's own Tag Cloud from the event. Participants first arrived for a welcoming dinner reception, and were given their nametags with Tag Clouds affixed. Explanation of the source texts was given when asked for. Informal observations and testimony at this event revealed the Tag Clouds often played leading roles in the conversations that ensued. One faculty member reported that the Clouds were the basis for or most-common referent in every single conversation she participated in; they were also frequently observed to be the first subject of inquiry following the exchange of names. These observations suggest both the initial utility of Tag Clouds as "ice-breakers" and their continued usefulness as a resource for conversation topics. The tangible affordances of a *wearable* visualization were also evidenced as faculty often pointed to their own Clouds while making self-referential statements and pointed to others' Clouds when making inquiries. Also, being able to read a person's largest words from a distance appeared to enable "semantic probing" to assess the desirability of interaction in advance of an actual encounter.

Future Considerations

Overall, people used the designed affordances far more than expected. Most wore their Cloud nametags again on the second day of the retreat, though reference to them dropped nearly to zero. This highlights the visualization's specific utility during the formative stages of collaboration. Several important critiques came out of the H-STAR user experience. Participants desired editorial control over their own Tag Clouds so as to produce more accurate self-representations, and wished that most-recent publications be the primary source of text data instead of curriculum vitae (to exclude out-of-date research interests). Some desired to see animated visualizations of research interests over the course of their career. This last idea points to future work on Wearable Tag Clouds as computational devices which could, for example, dynamically highlight the interests shared in common by interacting individuals.

Future design-based research on this paper's topic is important because of the identified potential for wearable information visualizations to positively impact collaborative research communities.

Endnotes

(1) Common English words (and, the, they, etc.) are ignored due to their overwhelming frequency and lack of subject relevance. In addition, the Porter Stemming algorithm (Porter, 1980) is used to group words that share a common root.

(2) Other ordering, weighting and layout schemes are possible, and future research will explore these possibilities. Note that color value is also used to show relative word frequencies, in a way that mimics depth-perception cues.

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Massively Multiplayer Online Games & Education: An Outline of Research[1]

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Abstract: For those with a vested interest in online technologies for learning, the knowledge and skills that constitute successful participation in massively multiplayer online games (MMOs) places them squarely among the most promising new digital technologies to date. In this paper, I broadly outline the qualitative results of a two and a half year cognitive ethnography of the MMO *Lineage* and describe the current trajectory of research we are now pursuing, based on those findings: (a) the empirical investigation of focused research questions in order to document and analyze those core practices that constitute gameplay in virtual worlds, and (b) the development of educational activities for after school clubs that capitalize on those capacities found throughout our research. This essay concludes with a reflection on the multiple relationships between games and education, highlighting the potential for such technologies to transform not only the means of education but also perhaps the goals.

Videogames?

When people think of "videogames," what often comes to mind is arcade games like *PacMan* or puzzle games such as *Bejeweled* or first person shooters rife with guns and explosions and twitch-speed antics in titles such as *Doom*. In truth, however, there is a very wide range of successful games on the contemporary market that reveals the immense variability in what and how gamers actually play: sports games such as *Madden NFL* where you can play through the entire season of your favorite football team, adventure games like *Myst* that let you journey into beautiful and mysterious worlds unravel the game's core story, turn-based strategy games such as the *Civilization* series where you can "replay history" (Squire, 2004) from 4000 BC to the present using accurate real world maps, online games such as *World of Warcraft* that allow you to create a digital version of your corporeal self and inhabit new worlds and new communities, and even music videogames like *Guitar Hero* where you become the rock star using a guitar controller instead of a joystick– all to name a few. Such games constitute a broad array of genres, the variety and complexity of which is often quite surprising to those who do not play. The research outlined herein focuses on one genre of game in particular, *massively multiplayer online games* (MMOs). The remainder of this article is dedicated to convincing other researchers interested in educational technology as to why.

Massively Multiplayer Online Games

Massively multiplayer online games (MMOs) are highly graphical 2 or 3-D videogames played online (see Figure 1) allowing individuals, through their self-created digital characters or "avatars," to interact not only with the gaming software (the designed environment of the game and the computer-controlled characters within it) but with *other players'* avatars as well. These virtual worlds are persistent social and material worlds loosely structured by open-ended (fantasy) narratives, where players are largely free to do as they please – slay ogres, siege castles, barter goods in town, or shake the fruit out of trees. They are notorious for their peculiar combination of designed "escapist fantasy" yet emergent "social realism" (Kolbert, 2001): in a setting of wizards and elves, ogres and dragons, people save for homes, create basket indices of the trading market, build relationships of status and solidarity, and worry about crime. For those who have never logged into an MMO, it is hard to believe such virtual worlds are available for the monthly price of a fast food dinner and not some mere fantasy found only in sci-fi novels or television.

Yet, these virtual worlds are significant. If we look at the current global player populations of just those three game titles included in the research described here – *Lineage I* with 1.5 million players, *Lineage II* with 1.4 million, and *World of Warcraft* with 8.0 million (and still growing) – we find a population base of roughly 10.9 million global. Such numbers rival every U.S. metropolis, including even New York. When this line of research into such online play environments was initiated five years ago, virtual worlds were still considered a somewhat "fringe topic" in academics; today, their empirical investigation, while still considered somewhat novel in Education, has generated some of the most cutting edge research in many well-established fields including economics (Castronova, 2001, 2002), law (Balkin & Noveck, 2006; Hunter, 2003; Hunter, & Lastowka, 2005), sociology (Cherny, 1999;

Ducheneaut, Moore, & Nickell, 2004; Taylor & Jakobsson, 2003), anthropology (Taylor, 2006b), and psychology (Turkle, 1994, 1995; Yee, 2005) (for a full review, see Steinkuehler, in press-a).

The virtual economies of MMO are surprisingly quite significant as well. Each virtual world has its own in-game currency, in-game goods, in-game trading, and therefore in-game economy. Despite the standard terms of the End User License Agreements (EULAs) of the companies who create and own such titles, many people now buy and sell virtual currency and items outside the game on online trading sites such as *eBay*. People pay real dollars for virtual money and goods. In 2001, the economist Castronova set out to measure the financial import of such virtual worlds based on such transactions only to find that the economies of some virtual kingdoms rival the economies many important "real world" countries. Take Norrath, for example, the virtual world of the MMO entitled *EverQuest*. By Castronova's 2001 calculations, Norrath was the 77th largest economy in the real world with a GNP per capita somewhere between Russia and Bulgaria. One platinum piece, a piece of currency in the virtual kingdom of Norrath, was trading on real world trading markets higher than both the Yen and the Lira. Thus, if the general popularity of virtual worlds fails to impress, perhaps their sheer economic value in terms of the good old American dollar surely might.

Figure 1. Screenshot from the MMO *World of Warcraft* showing the in-game virtual world and interface.

MMOs & Learning: An Outline of Research

MMOs, however, are important not just in terms of popularity or economics; they are *educationally* important as well. For those of us with a vested interest in online technologies for learning, the kind of individual and collaborative knowledge and skills that constitute successful participation in MMOs is what places them squarely among the most promising new digital technologies to date. In this paper, I outline in very broad strokes the qualitative results of a two and a half year cognitive ethnography of the MMO *Lineage* (both I & II) completed in 2005 and then describe the current research program we are now pursuing based on those findings. With a generous grant from the MacArthur Foundation, our research team is investigating focused research questions, based on previous research and contemporary definitions of digital media literacy, toward the end goal of not only to empirically document and analyze those core practices that constitute gameplay in virtual worlds but also, and ultimately, to build educational activities for after school clubs that capitalizes on those capacities found throughout our research (see Figure 2). This essay concludes with a general reflection on the multiple relationships worth consideration between games and education, highlighting the potential for such technologies to transform not only the means of education but also perhaps even a few of the goals as well.

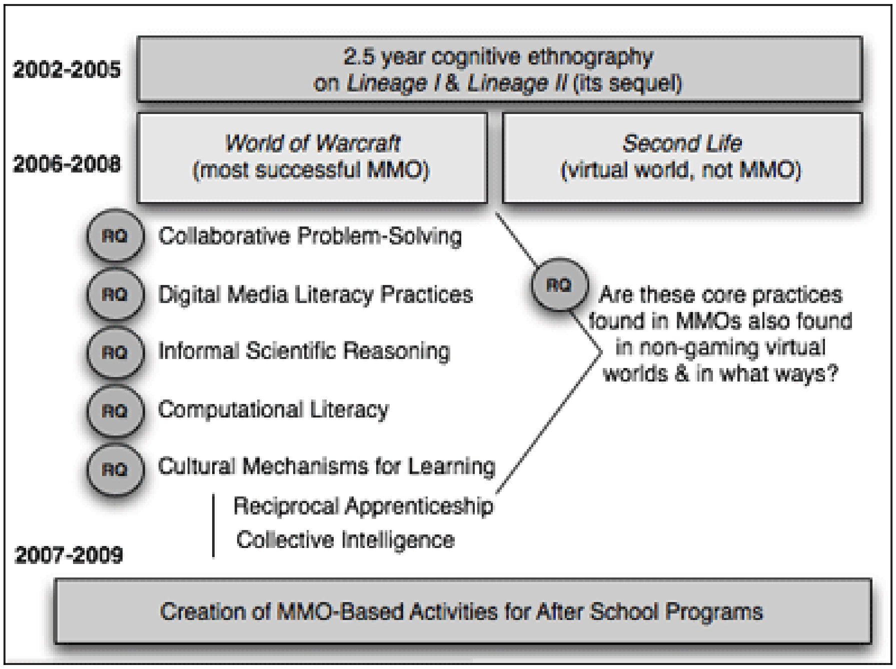

Figure 2. An overall outline of the three phases of this research.

Laying the Foundation: Cognitive Ethnography

In 2001, when this research was first conceptualized, there was a paucity of research on MMOs and learning. While previous small studies had focused on specific practices related to cognition and learning such as playstyle (Bartle, 1996), gender (Bruckman, 1993; Danet, 1998; Herring, 1996), race (Nakamua, 1995), communication (Carlstrom, 1992; Clodius, 1996a; Masterson, 1996) ritual (Clodius, 1995, 1996b) & identity (Clodius, 1997; Dibbell, 1998; Ito, 1997; Raybourn, 1998; Suler, 1996; Turkle, 1994, 1995), little could be found in terms specific to education and most consisted of only web-published essays and theses. Yet the question remained: If individuals were engaged in such worlds, oftentimes for extended periods to the detriment of other forms of leisure pursuits (such as television), what were they learning from it, if anything? While there were several ethnographic attempts to document the social customs and mores of such environments, little could be found that might answer the simple question: What, if anything, was the intellectual merit of playing in virtual worlds?

Cognitive ethnography (Hutchins, 1995) – the description of specific cultures in terms of cognitive practices, their basis, and their consequences – was chosen as the primary research methodology during the first phase of this research as a way to build a basic foundation toward answering this seemingly simple question. This "thick description" (Geertz, 1973) included roughly 28 months of participant observation in the game, several thousand lines of recorded and transcribed observations of naturally occurring gameplay, collections of game-related player communications (e.g., discussion board posts, chatroom and instant message conversations, emails) and community documents (e.g., fan websites, community-authored game fictions, company- and community-written player manuals and guidebooks), and interviews with multiple informants. The main focus throughout this initial phase of the research (Steinkuehler, 2005) was to document and analyze the forms of cognition and learning that make up successful MMO gameplay. At the risk of gross simplification, the broad results were that participation in such worlds crucially entails:

- Complex forms of *socially and materially distributed cognition* including the coordination of people, (virtual) tools, artifacts, and text, across multiple multimedia, multimodal "attentional spaces" (Lemke, n.d.) (Steinkuehler, 2006c),
- *Collaborative problem solving practices* in cross-functional teams within the game and distributed fandom communities beyond them, both of which emulate key forms of collaboration espoused in "new capitalist" workplaces (Steinkuehler, 2006a, 2006b, 2006e),

- *Novel literacy practices* including the use of highly specialized forms of language for in-game social interaction and genres of story-telling, fan fiction writing, and discursive argumentation on game-related forums (Squire & Steinkuehler, 2005; Steinkuehler, in press-b),
- *Scientific habits of mind* (American Association for the Advancement of Science, 1993) such as hypothesis testing and revision, and model-based reasoning (Steinkuehler & Chmiel, 2006; Steinkuehler & Duncan, 2007),
- Forms of *computational literacy* (the understanding and use of computational models, such as algorithms or code, to conceptualize a problem, diSessa 2000) represented by player-generated artifacts such as user interface modifications or "mods" (Steinkuehler, 2006d), and
- Mechanisms for learning crucial to success in those above such as *reciprocal apprenticeship* (Steinkuehler, 2004), through which individuals enculturate one other into routine and valued practices and perspectives, and a culture of *collective intelligence* (Levy, 1999; Jenkins, 2006) evidenced in the joint creation, maintenance, and transformation of shared online repositories of community knowledge and skills (Steinkuehler, 2006a).

This list represents most of the core social/intellectual practices that characterize MMO gameplay, although not all (for a full review, see Steinkuehler, 2005); even this partial inventory, however, is non-trivial, including some knowledge and skills that rival those found in many of today's typical classrooms. As to the question, "is there educational potential for virtual worlds such as those found in standard MMO gameplay," the answer appeared to be a resounding *yes*.

Focused Empirical Investigations in Two Virtual World Contexts

The second phase of this research program, now currently underway, is comprised of focused and specific research questions pursued using a mix of both qualitative and quantitative methods in two contexts: (a) the MMO *World of Warcraft*, now the single best-selling computer game on the market with over eight million players worldwide, and (b) *Second Life*, a popular virtual but non-game online environment. In effect, we are comparing a "gaming" context for play to a "virtual frontier" context more ostensibly focused on recognizable and consequential entrepreneurship based on the premise that, in order for us to successfully design informal learning activities based on virtual worlds, we need to understand which patterns of practice are game-specific and which can be generalized to virtual world communities more broadly. Our goal is to go beyond mere plausibility argument for the *potential* of virtual worlds for learning to look more systemically at what knowledge and skills they foster and in what ways. Based on ethnographic findings (outlined above) and a contemporary definition of digital media literacy that crucially includes not just *critical consumption* of media but also and as importantly *production* (Gee, 2003), our research group is targeting five main areas for research selected as those most fruitful for further exploration: (1) collaborative problem-solving, (2) digital media literacy practices, (3) informal scientific reasoning, (4) computational literacy, and (5) cultural mechanisms for learning (see Figure 2). Given space constraints, I will describe three of these five strands of research in order to illustrate the shape and texture of such activities and demonstrate why they are particularly worth further study: (1) collaborative problem-solving, (2) digital media literacy practices, and (4) computational literacy.

Collaborative Problem-Solving

In MMOs, individuals engage in collaborative problem solving as a key component of regular gameplay. Here, groups of five or more players join together to tackle problems more challenging than one person alone could typically solve. For example, in *World of Warcraft*, players regularly enter "instances" or "raids" together to battle monsters of various sorts while making their way through, say, a dungeon or a jungle outpost (see Figure 3). Such gameplay is called "instancing" or "raiding" since, as the game is designed, the software renders the chosen area of the world as a single instance that only those members of the group can access, thereby allowing them to proceed through the game content without interruption from other players within the game space. What is curious about such activities is not the software's rendering of the content per se but rather the way in which such groups function in order to succeed. Specifically, in such endeavors, a core group *takes the given task or project through completion* from planning through to follow-up, functioning only on a *semi-permanent basis* by dissolving once the goal is completed. The group is comprised of individuals from *different functional areas* (for example, a healer versus a damage-dealer) yet *redundancy or overlap* is built into such configurations so that, should any one person need assistance, another group member is able to take up the proverbial slack. Instancing groups (or raid parties) are *self-managed*, with a *group goal* (e.g., completion of the given dungeon area) yet *individual accountability* (e.g., the healer must successfully heal or risk policing of their behaviors if not outright removal from the group).

Figure 3. Screenshot from the MMO *World of Warcraft* showing an in-game collaborative problem-solving "raid".

Such structural features are important, as they not only describe collaborative problem solving within the game but also, as luck might have it, collaborative problem-solving within many contemporary workplace settings. They are, in fact, *cross-functional teams* (Fredericks, & De Lia, 2005; Lindborg, 1997; Michalski, 2005; Parker, 2002) – a key feature of many of today's "new capitalist" corporate workplaces such as those found in global financing or technology. In effect, the structures of collaboration found in online games parallels the structure of collaboration that increasingly marks high-end workplaces. While it seems counter-intuitive that running instances with joint problem-solving groups in the context of a game might train an individual for teamwork in today's workplace, the similarities between the two forms of collaboration are quite striking and therefore warrant further research.

Literacy practices

MMO gaming is participation in a constellation of literacy practices (Steinkuehler, in press-a, in press-b), one with fuzzy boundaries that expand with continued play: What is at first confined to the game alone soon spills over into the virtual world beyond it (e.g., websites, chatrooms, email) and even life off-screen (e.g., telephone calls, face-to-face meetings). The online fandom that surrounds successful game titles is a rich yet nebulous sphere of multimodal multimedia including websites, blogs, threaded discussion boards, fan fictions, fan art, annotated game screenshots, cartoons, chatrooms, instant messaging, in-character emails, and even voice over IP (VoIP). In order to succeed in the game over time, participants must increasingly engage with the online fandom beyond the virtual world itself in order, for example, to research strategies for success against various in-game challenges, or to develop deeper understandings of the class of character they play not only by using their own in-game experiences to better understand fandom texts (such as those listed above) about their given class but also by using such texts to better understand their own experiences.

Like all interpretive communities, MMO gamers take up the symbolic, cultural materials offered them by media to collectively create the form and substance of their own cultural worlds (Squire & Steinkuehler, in press; Taylor, 2002, in press). As such, they are no different from the folk cultures of old (Jenkins, 1998), except that, now, the consumers have increasingly user-friendly tools at their disposal to work with, including online access to sociotechnical networks that enable their easy distribution, such as fan groups and guilds. Consider, for example, the fan fiction excerpt shown below that circulated through much of *Lineage* fandom in 2003.

Blinding Twilight
by [redacted]
for [redacted]

As dawn eclipsed the town of Aden, it seemed that its light would never reach the end of the grand city. Built under the tyrannical rule of Ken Rauhel and the corrupt mage Cerenis, it seemed almost impossible that such a beautiful city was grounded in their despotic ideals. I looked across the horizon and nudged at [redacted], who had fallen asleep during last night's vigil

Figure 4. Excerpt from a *Lineage* fan fiction story.

In it, the author writes about a pseudo-fictional adventure – partially based on an actual occurrence, partially based on the genre conventions of medieval fantasy stories. The story is written at a grade level appropriate to the author's age; however, what is most interesting here is the purpose for which he purportedly wrote it. The story is dedicated to the second main characters appearing in its pages – a girl gamer roughly the author's age. In one email distribution of the story, the author writes, "I included a new story if you would like to read or post up, its awesome ^^ [raised eyebrows] even though I just used it to hit on this girl..."

It is difficult to imagine another cultural space in contemporary American youth culture at least in which writing a short story might be viewed as a recognizable way to court girls. In the context of MMOs, however, such writing is a central and highly valued practice. Here, adeptness with the pen, so to speak, carries a certain social status such that those who show exceptional skill in the creation of content oftentimes develop a rather large following. Moreover, in these contexts, such writing is typically not considered ancillary to normative gaming but rather a central part of what it means to participate. The following in-game social exchange illustrates:

SharpPaw	oh yea! to celebrate me coming back to pledge &
SharpPaw	being rank ive decided to write another story!
SharpPaw	for site!
Adeleide	omg do it! We need more stories!
SharpPaw	^^ o'course
SharpPaw	in fact ive planned it
SharpPaw	I got the PERFECT story idea the other day when
…	…
SharpPaw	its called An Old Knight's Tale
SharpPaw	youll see it within the next 2-3 months
Adeleide	wow! Do u like to write in ur spare time?
SharpPaw	well na I like to play this in my spare time

In this exchange, a beginning high school student who is on summer break discusses the short story he has recently decided to author in commemoration of rejoining the guild and being promoted in rank (after being grounded from gaming for a while until he raised his grade to his mother's satisfaction). When asked whether he likes to write in his spare time, he responds, somewhat baffled, "well na i like to play this in my spare time." In the context of MMOs at least, adolescents appear perfectly willing to engage in long, thoughtful writing projects – "2-3 months" planning, not including the initial work done prior to this exchange – in their own spare time, not as isolated literary "assignment" but as part and parcel of what it means to game online. Our current undertaking, then, is to better articulate the forms of literacy practice fostered in MMOs, who engages in them, to what extent, and why.

One explanation for this willingness to engage in such intellectual labor has to do with the way in which virtual worlds function as a new "third place" (Steinkuehler & Williams, 2006; cf. Oldenburg, 1999). By providing spaces for social interaction and relationships beyond the workplace and home, MMOGs have the capacity to function as one novel form of a new "third place" for informal sociability much like the pubs, coffee shops, and other hangouts of old. Moreover, participation in such virtual "third places" appears particularly well suited to the formation of bridging social capital – social relationships that, while not usually providing deep emotional support, do typically function to expose the individual to a diversity of worldviews (Steinkuehler, 2006d). Given the unfortunate rise of fundamentalism in the face of globalization (Giddens, 2006), such exposure to diversity is a valuable thing indeed.

Computational literacy

As a final example of the specific areas of investigation currently underway, consider the creation, adaptation, and use of game "mods" (short for modifications), which are derivatives of a given, professionally released game title into something new. In *World of Warcaft*, for example, modding practices take the form of so-called user interface (UI) "add ons" created by and for the community of players themselves. UI add-ons are essentially patches to the game software that change the user interface in some way –improving the structure and function of the interface by increasing the number of action buttons available, or diagnostic tools that increase the game's functionality by allowing the user to access information on their own performance in game and/or the performance of others. UI Mods play a vital role in the gaming community, providing the tools and functions crucial to in-game success. Some UI add-on's have developed such a following that not only do some guilds no longer allow their members to run instances without them (Taylor, 2006a) but also, in some cases, they are incorporated by the company who owns the title (Blizzard) directly into the original gaming software itself.

Such creations are *computational literacy artifacts* (diSessa, 2000): made objects that evidence not merely computer literacy (such as the ability to burn digital files to a CD) but rather the ability to understand and use computational models, such as code or a mathematical equation of some form, to conceptualize and solve a given problem. In interviews with those community members who create such software, an interesting pattern emerges: *Users of mods become critics/analysts of mods become creators of mods*. For some, modding replaces gaming entirely, with "building software" becoming the ultimate "end game" (Steinkuehler, 2006f). To be sure, the modding community of *World of Warcraft* represents only a small minority of actual players (which raises the research question of what gateways and barriers to such practices exist); however few such add-on creators may be, however, their products function as hubs in the socio-technical network, calibrating the gameplay of others' in tangible ways. For example, at last check, the number of downloads for "Titan Panel" mod was over six million, for "Recap" mod over 285,000. Compared to the average number of readers of an academic journal article (five), such large followings give pause for thought.

Designing MMO-Based Activities for After School Programs

Our current phase of research (outlined above) aims to better understand the form and structure of naturally-occurring, informal communities in virtual environments across two contrasting contexts; however, such an understanding is not the end goal in and of itself. Instead, it is our belief that such basic research can then be leveraged toward the development of intentional learning environments, specifically those designed around virtual worlds. Innovative NSF projects such as Harvard University's *River City* (e.g., Dede, Ketelhut, & Ruess, 2003) and Indiana University-Bloomington's *Quest Atlantis* (e.g., Barab, Arcici, & Jackson, 2005) have begun to tackle the complexities of designing virtual worlds in the service of learning, yet to date such work has been done largely outside the purview of emerging research on such technologies out "in the wild" (Hutchins, 1995). In contrast, our goal is to build prototype after-school activities based on a more robust understanding of what educationally valued practices arise out in virtual worlds in natural contexts. In so doing, we hope to build a better bridge between kid's media literacy practices outside of school and those promoted within them. By putting pressure on schools to reform through the promotion and viral spread of innovative after-school programs while, at the same time, opening up access to such worlds of practice to students who might not have such access otherwise, this research hopes to address the current digital disconnect (Levin & Arafeh, (2002) between the use of online technologies in and out of classrooms.

Toward these ends, the final phase of this project focuses on the development of educational activities, to be implemented in the after-school incubators established here at University of Wisconsin-Madison, that take what we have learned about digital media literacy communities in the context of virtual worlds and, building on those findings, recreate similar communities of practice in informal contexts for learning. Because the structure of these activities is contingent on findings from the second phase of research currently underway, their form and structure will, in effect, provide a context for conducting design experiments that test theories about what mechanisms (both technical and social) foster which intellectual practices and how (i.e., for testing the claims generated through empirical analysis throughout the current phase of research). By demonstrating the potential of such online worlds/cultures, first out "in the wild" and then in informal after-school contexts, we hope to maybe one day change the very culture of schooling into something more relevant, promising, and transformative for all.

Conclusions

While the research outlined herein ultimately focuses on games *in* classrooms – specifically, using off-the-shelf virtual worlds such as *World of Warcraft* or *Second Life* in after school contexts – in truth there are multiple relationships between games and (in)formal classrooms worth consideration. Oftentimes, when the issue of "games and learning" is raised, there is a tendency to focus solely on the relationship between games *and* classrooms to the exclusion of all others – a fixation whose symptoms include a near obsessive focus on the question of what game-related knowledge and skills "transfer" to formal classrooms, despite the grand irony that it was always *classrooms* that were supposed to teach things that might transfer to life beyond them, not the other way around. Other relationships between games and classrooms can and do exist, however; for example, the relationship of games *as* classrooms. By thinking of games as learning environments in and of themselves, we can discern design principles in games that might be fruitfully applied to the design of other learning environments, be they classrooms, after school clubs, or corporate training retreats. In fact, it is this fundamental relationship that underlies much of the seminal work of James Paul Gee (2003). And too, of course, there is the notion of games *for* classrooms, exemplified in the development of *River City*, of *Quest Atlantis*, and the entire Serious Games movement to date. One relationship that often gets lost, however, is the simple fact of games *despite* classrooms. With more than eight out of every ten kids in America having a videogame console in the home, and over half having two or more (Rideout, Roberts, & Foehr, 2005), it becomes increasingly clear that games are *the new literacy*, whether those of us in education are willing to recognize them as such or not. From this perspective, we need to research and understand games for the sheer reason that they are, much to the chagrin of an older generation, one of the most important new cultural media to date.

In my own research, however, I have come to think of games as a new *gateway drug*. Based on our ongoing research, I find the most apt rhetorical framing of the question to be: How can games provide entrée into other intellectual practices outside the game that we, as a community, value? How and when and for whom might virtual games be a bridge to worlds beyond them? We know that games are a push technology, moving into the home and dragging computers, for example, in their wake (Williams, 2004), but we would be mistaken to think this merely a hardware or software issue. They bring with them important social and intellectual practices and dispositions as well. In these ways, MMO communities are push communities, functioning as our proverbial canaries in the coalmine when in comes to the life in the globalized online world. And, from this perspective, their empirical investigation now can only better prepare us for the radical changes to come, whether schools respond in efficacious ways or ultimately render themselves increasingly obsolete.

Endnotes

(1) This paper has been adapted for publication in *Educational Technology* magazine.

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Acknowledgments
This work was supported by the GLS [Games, Learning & Society] Group, a cooperative agreement between the Academic ADL Co-Lab and the University of Wisconsin-Madison, and by a generous grant from the MacArthur Foundation. Constance Steinkuehler is principal investigator. The ideas expressed herein are not endorsed by and may not be representative of positions endorsed by the sponsoring agencies.

Analyzing Collaborative Processes and Learning from Hypertext Through Hierarchical Linear Modeling

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Abstract: The purpose of this study was to understand how individual and group characteristics interact to produce a rich understanding of domain knowledge. Metanavigation support in the form of prompts was provided to groups of students who collaboratively used a hypertext system called CoMPASS to complete a design challenge. Multilevel analysis techniques were used to understand how the provision of metanavigation support to groups interact with group navigation behavior and learner's metacognitive awareness of reading strategies to affect individual learning. The findings of this study revealed that providing metanavigation support to the groups contributed positively in enabling students to gain a rich understanding of domain knowledge. Our findings also indicate that there was a significant negative interaction of students' metacognitive awareness and perceived use of reading strategies and the presence of metanavigation support while interacting with hypertext.

Purpose of the study

In recent years different methodological approaches have been used to measure and analyze collaborative processes while learning in technology-supported settings. Some of the approaches were: interaction and social network analyses (Jordan & Henderson, 1995; Kreijns, Kirschner & Jochems, 2003; Reffay & Chanier, 2003), various types of discourse analysis (Chinn, O'Donnell & Jinks, 2000), matrix analysis (Wortham, 1999), and content analysis schemes (De Wever, Schellens, Valcke, & Van Keer, 2005; Strijbos, Martens, Prins, Wim, & Jochems, 2005). However, many of these approaches focused on analyzing group discourse. We agree with Naidu and Jarvela (2006) that there is a need to move beyond focusing only on such analyses and direct attention toward understanding how critical attributes of CSCL contexts interact with group collaboration as well as with individual attributes of collaborative learners. Individual, group and context factors affect the types of interactions and the learning outcomes in a collaborative technology-supported setting and need to be taken into account while studying the dynamic process of collaborative learning. Analysis of learning at both the individual and the group unit of analysis is necessary (Stahl, Koschmann & Suthers, 2006)

Rummel and Spada (2004) argued that in order to "crack" the complex processes that take place in collaborative contexts we need to work towards developing a "methodological toolbox" which "could support an informed choice of appropriate methods of analysis" (p. 23). Quantitative methods such as multilevel statistical techniques could be useful tools when studying the relationships of variables with different levels and units of analysis. Such methods enable researchers to model the dependencies in the data and obtain more accurate relationships between variables of interest. Recent studies on collaborative learning in technology-supported settings have underlined that there is a "multi-faceted methodological problem" in this area of research (Fischer, Weinberger, & Mandl, 2004) and there is a need for more accurate research methods (in terms of validity and reliability) to assess the impact of learning and working in CSCL settings (Valcke & Martens, 2006).

The purpose of this study was to understand how individual and group characteristics interact to produce a rich understanding of domain knowledge. More specifically, we used multilevel analysis techniques to understand how cognitive attributes of collaborative learners might be interacting with group membership to affect learning. We designed and implemented support for navigation (metanavigation support) in the form of prompts to enable groups to think about the processes students use while interacting with online science texts and help them monitor and regulate these processes.

Research Context: Integrating CoMPASS in the science classroom

This study was a part of an implementation of CoMPASS (Puntambekar, 2006; Puntambekar & Stylianou, 2005; Puntambekar, Stylianou, & Hübscher, 2003; Puntambekar, Stylianou, & Jin, 2001) in sixth grade science classes. During this implementation, students used CoMPASS as a resource to find information and read about the science concepts and principles that were involved in the unit of 'Simple Machines'.

Affordances of CoMPASS

CoMPASS is a science hypertext system that has two tightly integrated modes of representation: a textual representation of the content units and a visual representation in a form of concept maps. CoMPASS maps are dynamically constructed and displayed with a fisheye view based on the strength of the relationships among concepts, illustrating graphically the relationships among key ideas in the text (see Figure 1). The maps show the local subnetwork of the domain and where the links lead to, enabling readers to see the relationships among the text units (concepts) and make thoughtful decisions of what paths to follow without getting lost or confused. CoMPASS also supports readers to study a science idea in multiple contexts by changing views (top right of screen in Figure 1).

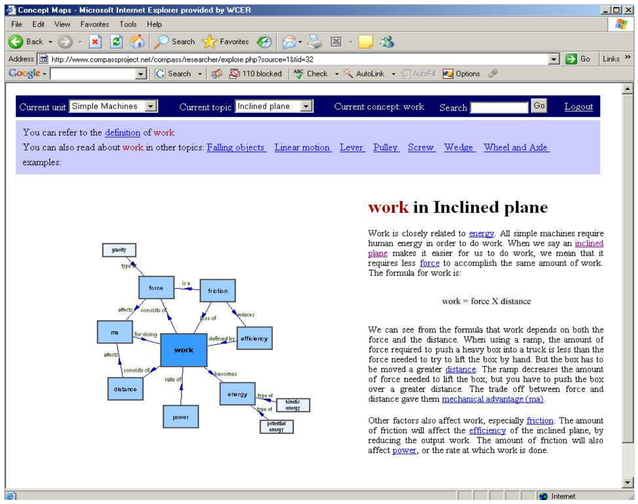

Figure 1. Textual and visual representation of information with 'work' as focus

In Figure 1 the reader has chosen to read about work in pulley. Work appears as the focal concept in the map and the text related to work appears in the right part of the screen. The concepts that are most closely related to work appear larger and closer to the focus whereas the concepts that are not as closely related to work appear in the periphery. The maps allow for exploration and support students to take multiple investigation paths based on their learning goals at any particular time.

Participants

The participants in this study were 121 sixth graders in four science classes being taught by two different teachers. The school was located in a university town in Connecticut. The students were from different ethnic backgrounds and academic abilities. Each class was randomly assigned to one of two conditions (metanavigation support, no support). Approximately equal numbers of students were assigned to each condition, with variation being due to uneven class sizes.

Students collaborated in groups of three or four while using CoMPASS to solve the "Pulley design challenge". The groups were formed based on teachers' perception of students' academic ability. Teachers decided to form groups of mixed ability levels so that students would benefit from each other during collaboration. The metanavigation support condition included 11 groups of students and the no support condition 15 groups.

Procedures

The study involved four sessions of 45 minutes that were conducted during the science class period. The *first session* involved an assessment of students' metacognitive awareness and perceived use of reading strategies while reading school-related materials through the MARSI (Mokhtari & Reichard, 2002) instrument. This inventory was administered online. The *second session* started with the presentation of the task. The task was a design challenge that required students to build a pulley device that would lift a bottle of water that weighed 600 grams off a table using the minimum amount of effort. Students were allowed some time to think about the requirements of the task and write down their initial ideas. Then, they were asked to collaborate in groups to plan their quest of finding information to solve the challenge. Groups were asked to read the information that was available for pulleys in the 'Simple Machines' unit in CoMPASS. Groups used CoMPASS for approximately 25 minutes. During the *third session* students were asked to continue their quest of searching information about pulleys in CoMPASS and finalize their pulley system designs. The groups in the metanavigation support condition received metanavigation prompts in a written format to guide their exploration in CoMPASS. Groups were allowed to use CoMPASS for approximately 25 minutes. The *fourth session* included an assessment of students' individual science knowledge through a concept map test that was administered in a paper and pencil format.

Providing Metanavigation Support

Metanavigation support in the form of prompts was provided to the groups in the metanavigation support condition to encourage them to monitor and regulate their navigation strategies in order to gain a rich understanding of science concepts while reading from hypertext. Metanavigation support was based on two indices that were informed by group's navigation path while interacting with the CoMPASS system.

The prompts were contingent upon students' navigation and were customized for each group. Log file information that captured groups' navigation path enabled us to assess their navigation behavior and decide what metanavigation prompts would be given to each group. Computer log files recorded information about what science concepts the groups explored while using CoMPASS, how much time they spent on each concept and what navigation tools they used to make their navigation choices. Two main indices from group's navigation path informed our decision of what type of metanavigation support each group needed: navigation choices and transitions among text units (see Table 1). Specifically, we were interested in whether or not the group members had chosen to read about the science concepts that were relevant to their learning goal and whether the transitions they made among the text units that were available in the hypertext environment would enable them to gain a rich understanding of the domain. For example, did the group make transitions to related concepts while reading about science concepts?

Table 1: Group navigation based on log file data

Log file information	Type	Description
Concepts visited	Non-goal related Goal related	Do students visit concepts that are relevant to their learning goal?
Transitions	No coherence Coherence	Do students make transitions to related concepts while reading?

Considering the binary state of each of these categories, we could have four different cases, described in the 'metanavigation support rules' cells of Table 2, as well as various combinations.

Table 2: Conditions for providing metanavigation prompts

<table>
<tr><th></th><th>Metanavigation support rules</th></tr>
<tr><td rowspan="2">Navigation choices</td><td>If choice of non goal-related concepts ⇒ encourage goal-related navigation</td></tr>
<tr><td>If goal-related navigation ⇒ encourage integration of science knowledge</td></tr>
<tr><td rowspan="2">Transitions</td><td>If transitions are to not related concepts⇒ encourage regulation of navigation behavior to make transitions between text units that are related while reading</td></tr>
<tr><td>If transitions are to related concepts ⇒ encourage integration of science knowledge</td></tr>
</table>

For example, the log file data of one of the groups indicated that they chose to read about science concepts that were not as relevant for solving the pulley challenge (i.e., 'kinetic energy', 'potential energy', and ‘power’) and did not read about goal-related science concepts such as ‘mechanical advantage’, ‘distance’, and ‘force’. For example, another group was reading about ‘work’. One possible transition to a related concept would be to read about ‘force’.

The metanavigation prompts were aimed at encouraging students to understand the affordances of the navigational aids in CoMPASS and use them to guide their navigation. The prompts encouraged students to (a) *think* about their goal and (b) to make *decisions about which concept to select next. The prompts were designed to help students* use the concept maps in CoMPASS to make thoughtful decisions of what paths to follow. As mentioned earlier, the concept maps in CoMPASS showed students the concepts were related to one another and to the topic.

Data Sources and Measures

Multiple sources of group and individual data were collected over the four sessions. Measures included student’s individual performance in the Metacognitive Awareness of Reading Strategies Inventory (MARSI) and a concept map test. Process measures included log file information that captured group navigation paths during the use of CoMPASS.

Pre-Assessment Instruments

Students’ metacognitive awareness and perceived use of reading strategies while reading school-related materials was assessed through the Metacognitive Awareness of Reading Strategies Inventory (MARSI) (Mokhtari & Reichard, 2002). MARSI consisted of 30 Likert-type items with a 5-point response format (1=“I never or almost never do this”, 2=“I do this only occasionally”, 3=“I sometimes do this-about 50% of the time”, 4=“I usually do this”, 5=“I always or almost always do this”). An overall total average MARSI score was calculated for each student indicating how often the student uses reading strategies when reading academic materials.

Measures during Intervention

Computer log files were used to look more deeply into the navigation paths of groups of learners in an attempt to detect differences in approaches to reading and learning from hypertext when providing metanavigation support. Log files recorded information about what science concepts the groups explored while interacting with the CoMPASS system in a chronological order. Two primary dimensions were used for the analysis of group navigation paths. The first dimension was based on whether groups chose to focus on science concepts that were related with their task goal. A goal-relatedness index was calculated by dividing the total number of goal related concepts visited to the total number of concepts visited. The second dimension was based on whether the groups made transitions to related concepts while reading the different text fragments. A transition-relatedness index was calculated by dividing the number of transitions to related concepts to the total number of transitions among concepts.

Post-Assessment Instruments

A paper and pencil concept map test was used to assess richness of students’ understanding of science concepts. The students were provided with a list of science concepts from which they were asked to create a concept map providing an explanation for each concept, making connections among concepts and stating how they are related. Two aspects of the maps were examined: the explanation provided for the concepts and the explanation provided for the connections among the concepts. Students’ concept maps were analyzed using a rubric that was developed in a study conducted by Puntambekar, Stylianou, and Hübscher (2003). Students’ responses were scored on a scale of 0-3 based on the depth of science understanding that they demonstrated. A score of 0 indicated an incorrect explanation, while a score of 3 indicated a complete and clear explanation for the concept or the connection. A concept ratio was calculated for each student by dividing the score that was given for the explanation of the concepts by the number of concepts included in the concept map. This ratio was a measure of student’s understanding of science concepts. A connection ratio was calculated by dividing the score that was given for the explanation of the connections with the number of connections in the map. This ratio was a measure of the depth of understanding of the relationships among science concepts.

Investigations and Data Analyses

The main research question that was addressed in this study was: To what extent can concept maps scores (explanations of concepts and explanations of connections) of students be predicted from the presence of metanavigation support while interacting with science texts, their individual metacognitive awareness of reading strategies and the group navigation behavior?

In order to analyze the data for this study, multilevel analysis techniques were used (Bryk & Raudenbush, 1992) with the use of the software HLM 6.01 for windows. Multilevel analysis techniques are helpful for taking into account dependencies that occur in datasets that have hierarchical structures. Accounting for such dependencies is especially important in order to reach more accurate estimates of the effectiveness of each independent variable on the outcome variable of interest. For the purpose of the current study, the data were gathered and analyzed on two levels. Level 1 included variables that were gathered on the individual student level; level 2 included variables that were gathered on the group level since the students were nested within groups.

Two-level HLM models were tested on two outcome variables. The first outcome variable was the concept ratio (CONCR), a measure of student's understanding of science concepts. The second outcome variable was the connection ratio (CONNECTR), a measure of the depth of understanding of the relationships among science concepts. For each outcome variable, the HLM analyses were performed in three stages. At the first stage, a null model was tested in which no independent variables were included in the analysis. The results produced by this model were comparable to random effects ANOVA which measured the variance within and between groups. At the second stage, the student-level independent variables were added to the model, while at the third stage the group-level independent variables were added. The independent variables were added to the model based on theory. However, cross-level interactions that were not significant were deleted from the final models.

The level 1 data included student level characteristics, which were those of the student's metacognitive awareness and perceived use of reading strategies while reading school-related materials (MARSI). The level 2 data included group level characteristics which were those of the condition that the students were in (whether they received metacognitive support or not), as well as the two navigation dimensions that were used for the analysis of group navigation paths. The first dimension was the goal-relatedness index (GOALNAV), a measure of whether groups chose to focus on science concepts that were related with their goal. The second dimension was the transition-relatedness index (TRANSNAV), a measure of whether the groups made transitions to related concepts while interacting with CoMPASS.

Table 3 includes a more detailed description of the variables used in the analysis. More specifically some descriptive statistics, such as the means, standard deviations as well as the minimum and maximum values of each variable are presented. As shown in Table 3, there was a difference in the averages of the two scores derived from students' concept maps (concept ratio and connection ratio). The average concept ratio score was higher than the average connection ratio score. It seems that students did not provide many complete and clear explanations for the connections among concepts in their concept map (mean=0.8). The table also shows that the average score of the goal-related navigation index was higher than the average score of the transition-relatedness index. Groups were better in choosing to read about science concepts that were related with their goal than making transitions to related text segments. As far as students' metacognitive awareness of reading strategies is concerned, it seems that on average students reported that they usually apply reading strategies when reading academic or school related material.

Table 3: Description of variables used in the models.

Name	Description	Level	Type	Minimum	Maximum	Mean	SD
CONCR	Concept Ratio in Concept Map	1	Outcome	.00	2.75	1.32	.63
CONNECTR	Connection Ratio in Concept Map	1	Outcome	.00	1.60	.80	.34
MARSI	Metacognitive Awareness of Reading Strategies Score	1	Predictor	1.30	4.70	3.11	.71
CONDITION	Indicator of whether the groups received metacognitive support or not	2	Predictor				
GOALNAV	Goal-related Navigation Index	2	Predictor	.00	1.00	.66	.31
TRANSNAV	Transition-relatedness Index	2	Predictor	.00	1.00	.57	.28

Results

Predicting Connection Ratio in the Concept Map Test

The first analysis that was performed wanted to examine the depth of understanding of the relationship among science concepts. This depth of understanding, also called the connection ratio (CONNECTR) was the first dependent variable that was examined with HLM. Equations 1-3 represent the final model for this sample.

Through these models we attempted to explain the differences that students hold in their depth of understanding of relationships More specifically, equation 1 represents the effects of each student's MARSI score on the CONNECTR variable. This equation examined whether each student's metacognitive awareness of reading strategies had an effect on their depth of understanding of relationships. Equation 2 represents the group level main effects of CONDITION, TRANSNAV and GOALNAV. This equation examined whether (a) the condition that the students were in (whether they had received support or not); (b) whether each student's group made transitions to related concepts; and (c) whether each student's group focused on concepts that were related to their goals, had an effect on their depth of understanding of relationships. Finally, equation 3 represents the interaction between the condition that each group was in with each student's MARSI score.

Level-1 Model (Student level)

$$\text{CONNECTR} = \beta_0 + \beta_1*(\text{MARSI}) + R \quad (1)$$

Level-2 Model (Group level)

$$\beta_0 = \gamma_{00} + \gamma_{01}*(\text{CONDITION}) + \gamma_{02}*(\text{TRNSNAV}) + \gamma_{03}*(\text{GOALNAV}) + Uo \quad (2)$$

$$\beta_1 = \gamma_{10} + \gamma_{11}*(\text{CONDITION}) \quad (3)$$

Table 4. Coefficients of the Connection Ratio Model.

Effect	Symbol	Coefficient	Standard error	T-ratio	Approximate df	p-value
OVERALL INTERCEPT	β0	0.411	0.160	2.560	22	0.018
CONDITION	β1	0.692	0.242	2.866	22	0.009
TRNSNAV	γ01	0.019	0.136	0.139	22	0.891
GOALNAV	γ02	0.324	0.119	2.713	22	0.013
MARSI	γ03	0.039	0.041	0.948	81	0.346
CONDITION*MARSI	γ11	-0.169	0.068	-2.503	81	0.015

As shown in Table 4, the students who were placed in groups with higher levels of goal navigation, also had higher levels of CONNECTR scores (γ02=0.324, p=0.013). This indicates that the students whose groups chose to focus on concepts that were related to their goals had more depth of understanding of the relationships among the concepts. However, the levels of TRANSNAV that the groups held (whether the groups made transitions to related concepts) did not appear to have any effects on the student's depth of understanding (γ03=0.019, p=0.891). The results of this analysis have also shown a significant interaction between the condition that the students were in (whether they had received support or not), with the student's metacognitive awareness (MARSI) (γ11=-0.169, p=0.015). The negative sign of the gamma weight indicates that the students who had received support, but who had lower levels of metacognitive awareness, also had lower levels of depth of understanding. Based on the same relationship, the students who had not received support, but who had high levels of metacognitive awareness also had lower levels of depth of understanding.

In order to determine the percentage of variance explained by the models, it was important to estimate the baseline variance that was accounted for in the null model, when no independent variables are added. Based on the unconditional model, the percentage of variance between groups was 11.09%. As a next step, the level 1 predictor (MARSI) was included in the model. Although this variable did not help explain any of the level 1 variance, it was kept in the model in order to test for its interaction with the condition. However, the addition of the MARSI variable did help explain 15.9% of the variance at level 2. Finally, when the final complete model was run, it was able to explain 3.3% of the variance in level 1, and 99.73% of the variance in level 2.

Predicting Concept Ratio in the Concept Map Test

The procedures that were mentioned above were also performed with the concept ratio (CONCR) as the dependent variable, which measured the student's understanding of science concepts. As a first step, the same complete model that was used above was tested with CONCR as the outcome variable. Since none of the coefficients were significant however, a stepwise deletion process was preformed. Equations 4-6 describe the final model that was used for this dependent variable.

Level-1 Model (Student level)

$$Y = \beta 0 + \beta 1*(\text{MARSI}) + R \quad (4)$$

Level-2 Model (Group level)

$$B0 = \gamma 00 + \gamma 01 * (CONDITION) + Uo \quad (5)$$

$$B1 = \gamma 10 \quad (6)$$

Equation 4 represents the level 1 effects of each student's MARSI score on the CONCR variable. More specifically, this equation examined whether each student's metacognitive awareness of reading strategies had an effect on their depth of understanding of science concepts. Equation 5 represents the group level main effects of condition, which demonstrated whether the condition that the students were in (whether they had received support or not) had an effect on their understanding of science concepts. Finally, equation 6 demonstrates that the effect of the student's metacognitive awareness on their understanding of science concepts is fixed, meaning that the relationship between metacognitive awareness and the student's understanding of science concepts is the same across all groups.

Table 5. Coefficients of the Concept Ratio Model.

Effect	Symbol	Coefficient	Standard error	T-ratio	Approximate df	p-value
OVERALL INTERCEPT	$\beta 0$	0.842	0.226	3.729	24	0.001
CONDITION	$\beta 1$	0.359	0.129	2.784	24	0.011
MARSI	$\gamma 10$	0.100	0.069	1.442	84	0.153

Table 5 describes the effect that each variable had on the dependent variable of interest (CONCR). The independent variable of MARSI was not significant in explaining the student's CONCR scores ($\gamma 10$=-0.100, p=0.153). This indicates that the metacognitive awareness of the students did not have anys statistically significant effect on their understanding of science concepts. However, the condition was significant ($\beta 1$=0.359, p=0.011), indicating that the students whose groups had received support, had higher levels of understanding.

In order to determine the percentage of variance explained by this second model, the baseline variance was estimated from the null model, where no independent variables were added. Based on the unconditional model, the percentage of variance between groups was only 7.93%. As a next step, the level 1 predictor (MARSI) was included in the model, which did not help explain any of the variance in any of the two levels. Finally, when the final complete model was run, it was able to explain 0.03% of the variance in level 1, and 96.02% of the variance in level 2.

Discussion and Conclusions

In this study we used multilevel analysis techniques to understand how critical attributes of a context (provision of metanavigation support to groups while reading from hypertext) interact with group collaboration (group navigation behavior) as well as with individual attributes of collaborating students (metacognitive awareness of reading strategies) to affect individual learning outcomes (understanding of domain knowledge assessed through a concept map test). An overall result that can be concluded from this study is that providing metanavigation support to the groups seems to have contributed positively in enabling students to gain a rich understanding of domain knowledge and have higher scores in the concept map assessment task. The predictive models that were generated using multilevel analysis techniques for both outcome measures in the concept map assessment task, suggest that the variability in concept maps scores (explanations of concepts and explanations of connections) at the group level was accounted for by the presence of metanavigation support. Although the group level variance was very small, for both outcome measures in the concept map test we were able to explain almost all of the group variance.

The variability in the scores for the explanations of the connections that each student provided in his/her concept map was accounted by the presence of metanavigation support, the goal related navigation index and by an interaction of his/her MARSI score with the presence of metanavigation support. The presence of metanavigation support and the goal related navigation index had positive significant main effects on the variability of the explanations of connections among concepts in students' concept maps. Students who collaborated in groups that were given metanavigation support and chose to read about concepts relevant to their learning goal gained a deeper understanding of the relationships among science concepts than students who were not given metanavigation support and did not choose to read about goal-related concepts. Our findings also indicate that there was a significant negative interaction of students' metacognitive awareness and perceived use of reading strategies while reading from traditional texts and the presence of metanavigation support while interacting with hypertext. If a student had a low MARSI score (reported that he/she is not using frequently reading strategies while reading from traditional texts) the metanavigation support seems not to have helped him/her gain a rich understanding of the domain, as shown in his/her explanations of connections concept map score. Also students who had a high MARSI score but were not provided with metanavigation support did not gain a rich understanding of the domain. Providing metanavigation support to groups whose members reported more frequent use of reading strategies might have stimulated collaborative interactions which led to deeper understanding of the relationships among science concepts.

Another finding of the study was that the models that were created using the multilevel analysis techniques were not effective in explaining the variance at the student level. The MARSI score was not a significant predictor of students' performance in the concept map test (explanations of concepts and explanations of connections). Other variables need to be used to predict the variance at the individual level. Reading comprehension and prior domain knowledge were found to be significant predictors of students' understanding of domain knowledge when we used regression analyses (Stylianou & Puntambekar, 2004). In this study we chose to add the MARSI variable at the student level because we were more interested in determining how metacognitive awareness of reading strategies interacts with group level characteristics (group navigation behavior and provision of metanavigation support to the groups).

Overall, applying Hierarchical Linear Modeling enabled us to model the dependencies in the data (in our case students within groups) and obtain more accurate relationships among the variables of interest. We argue that multilevel analysis techniques can help us unravel some aspects of the complex collaborative processes that take place in a technology-supported setting. For example, the communalities and dependencies that exist in various characteristics of students who are in the same groups violate the assumptions of many parametric test procedures such as Analysis of Variance (ANOVA) and Regression. If we were to use such methods, no inferences of individual behavior would have been made based on the behavior of the group. In order to account for dependencies within the group, proper statistical analyses such as Hierarchical Linear Modeling could be used. It is important, though, to study collaborative processes from multiple perspectives (Hmelo-Silver, 2003; Rummel & Spada, 2004) and apply different methodological approaches (quantitative as well as qualitative methods) to understand the complexity of interactions and learning in such dynamic contexts.

Our future research plans are to "crack" the collaborative interactions of groups by examining audio data of peer interactions during navigation. We plan to focus on groups whose members had high MARSI but not given support and groups whose members which had high MARSI scores but not given support and investigate the negative interaction in the connection ratio predictive model. We will attempt to understand the richness of information contained in a collaborative interaction and identify what aspects characterize good collaboration which might lead to in-depth understanding of domain knowledge. Such analyses can contribute to our understanding of the reading comprehension processes employed while interacting with hypertext. Identifying how readers navigate digital texts and what kind of support they need while processing nonlinear information will be an important contribution in the hypertext as well as the literacy research fields.

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Acknowledgments

This research was supported by National Science Foundation's early career grant (CAREER #9985158) to Dr. Sadhana Puntambekar. We thank the students and teachers who participated in the study.

A Framework for Eclectic Analysis of Collaborative Interaction

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Abstract: The interactional structure of learning practices is a central focus of study for CSCL, although challenges remain in developing and pursuing a systematic research agenda in the field. Different analytic approaches produce complementary insights, but comparison is hampered by incompatible representations of the object of study. Sequential interaction analysis is promising but must be scaled to distributed and asynchronously mediated settings. Building on recent analytic work within our laboratory, we propose a framework for analysis that is founded on the concepts of *media coordinations* and *uptake,* and utilizes an abstract transcript representation, the *dependency graph*, that is suitable for use by multiple analytical traditions and supports examination of sequential structure at larger scales.

Introduction

Learning in collaboration with others is the foundation of Computer Supported Collaborative Learning (CSCL). An overview of the historical development of the field (Stahl, Koschmann, & Suthers, 2006) reveals the presence of several research traditions, including an analytic tradition that began with a conception of collaboration as a "continued attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995). More recently, there have been calls to focus work in the field on the study of "the practices of meaning-making in the context of joint activity" (Koschmann, 2002) or "intersubjective meaning-making" (Suthers, 2006b), from which "group cognition" (Stahl, 2006) emerges. The common emphasis is on the interactional structure of collaborative learning. Diverse lines of work exist in CSCL: we study interaction in different media, examine phenomena ranging from micro-episodes in small groups to large communities over periods of weeks to months, and analyze data using various "qualitative" and "quantitative" analytic approaches. In order to enable the cross-pollination of these different lines of work, there is a need for shared definitions and a common formalism. The work in our own laboratory spans some of this diversity, including study of co-present and distributed interaction with various synchronous and asynchronous media, and applying experimental and ethnographic methodologies at scales including pairs, small groups and online communities. Because of this diversity in our own work, we have encountered the need for greater theoretical and methodological dialogue; a need that also exists in the field of CSCL as a whole. We are committed to studying collaborative learning as a mediated interactional accomplishment, but wish to do so in settings beyond micro-episodes of synchronous interaction, and to apply a mixture of methods for hypothesis generation and testing. In this paper, we report on a framework for eclectic analysis of collaborative interaction that we have developed for our own work, in hopes that adoption by others may increase dialogue within the field as well. The framework is based on the concept of *uptake* and a few associated theoretical commitments that are necessary to define interaction as a common object of study. The primary feature of this framework is an abstract transcript notation—the *dependency graph*—that offers a common representational basis for diverse analytic methods applied to various media and interactional situations. The remainder of this paper documents the motivations, theoretical foundation, and practical aspects of the framework that has resulted, with selected examples.

Motivations

The approach is based on several years of our own analytic work, initiated to expose the practices of mediated collaborative learning in data from our prior experimental studies. In an analysis undertaken in order to understand how knowledge building was accomplished via synchronous chat and evidence mapping tools, we used the concept of *uptake* to track interaction distributed across these tools (Suthers, 2006a). Subsequently, we began analyzing asynchronous interaction involving threaded discussion and evidence mapping tools (Suthers, Dwyer, Vatrapu, & Medina, 2007). The uptake analytic framework was further developed to handle the asynchronicity and multiple workspaces of these data. Below we summarize the view of learning underlying our current work, assess prevalent analysis methodologies in relation to our needs, and then discuss additional requirements for eclectic methodologies.

Learning as an Interactive Process

Although we believe that the framework we offer in this paper can support analyses under a variety of views of learning, the framework is motivated by our own views of how learning takes place in social settings. We conceive of learning as an interactional process of change. This conception of learning as interactional is compatible with theories of learning that identify individuals (Beck, 1997; Chi, Bassok, Lewis, Reimann, & Glaser, 1989), socially embedded individuals (Doise & Mugny, 1984; Vygotsky, 1978), social systems (Engestrom, 2001), or communities (Wenger, 1998) as the locus of change. Learning need not be deliberately sought: it is a result of participants' attempts to make sense of a situation. *Meaning-making*, as we call it in this paper, takes place at multiple levels: solving a problem, maintaining interpersonal relationships, and/or affirming identity in a community (Bronckart, 1995). To study learning in social settings we must necessarily study individual trajectories of meaning-making and how they intertwine in practices of intersubjective meaning-making (Suthers, 2006b). In such settings, the meaning of a given contribution is best understood as a function of its relationships to prior interactions, and indexically with respect to the physical and social context (Koschmann, Zemel, & Stahl, 2004). Meaning-making is mediated by the physical and social environment in diverse ways (Wenger, 1998; Wertsch, 1998). As designers of media for online learning, this mediation gives us an avenue for influencing meaning-making and learning through the social affordances of the tools that we design (Suthers, 2006b).

Statistical Aggregation

Many approaches to the study of learning follow a quantitative paradigm in which contributions (or elements of contributions) are annotated according to a well-specified coding scheme (e.g., De Wever, Schellens, Valcke, & Van Keer, 2006; Rourke, Anderson, Garrison, & Archer, 2000). Statistical methods are then used to characterize aggregate behaviors that may then be compared across experimental conditions. This approach has three significant strengths. First, a coding scheme is a concrete classification of behaviors that supports mathematical methods for estimating consistency (reliability) between multiple analysts. Second, the approach has well defined statistical methods for comparing results from multiple sources of data such as experimental conditions and replications of studies. Third, this approach can scale up analysis by quantifying data across large groups. The trade-off is that "coding and counting" obscures the sequential structure and situated methods of the interaction. "Coding" assigns the meaning of an act as an isolated unit, and therefore either does not take the indexicality of this meaning into account or fails to record the evidence on which the analyst relied in making a judgment. "Counting" or statistical aggregation loses the sequential methods by which media affordances are used in particular learning accomplishments, making it more difficult to identify important design elements at the same temporal and spatial grain as the actual interaction itself.

Sequential Analysis

A contrasting approach finds the significance of each act in the context of the unfolding interaction. This approach includes Conversation Analysis (Goodwin & Heritage, 1990; Sacks, Schegloff, & Jefferson, 1974) and Interaction Analysis (Jordan & Henderson, 1995). Typically, these methods repeatedly examine the micro-structure of short interaction segments to uncover the methods by which participants make their actions accountable to each other (Garfinkel, 1967). This approach is a complement to statistical aggregation and has the opposite strengths and weaknesses. These methods document the actual practices of learning by attending to the sequential structure of the interaction, producing detailed descriptions that are deeply situated in the medium of interaction. However, sequential analyses are often time consuming to produce and difficult to generalize to different media or groups. A micro-analysis can capture sequential properties because analysis is focused on short interactions that an analyst can view and review, but progressively larger structures escape its grasp. The family of methods loosely classified as "exploratory sequential data analysis" (Sanderson & Fisher, 1994) address some of these concerns with computational support for statistical and grammatical analysis (Olson, Herbsleb, & Rueter, 1994).

Additional Requirements

The different environments and media under examination have spawned multiple environment- and medium-specific analytic notations. For example, ethnography relies to a large extent on freeform notes taken by observers. Studies of conversation have used simple transcripts of utterances (Roschelle, 1992) and more detailed transcripts using Jeffersonian notation (Sacks et al., 1974). Video has become the standard recording medium for studies of practice (Jordan & Henderson, 1995; Koschmann et al., 2004). Video analysis tools (e.g., Pea, 2006; Woods, 2006) provide support for exploring and annotating video records, but the annotations are tied to this medium. Online interaction simplifies the creation of transcriptions: software tools can record a detailed and comprehensive log of an interaction. However, online media introduce asynchronicity and hide the production of contributions (Clark & Brennan, 1991), introducing different demands on analytic notations. Analysis of the simultaneous use of many communication media and channels has relied on ad hoc, eclectic representations (see, for example, Hmelo-Silver, 2003; Suthers, 2006a). Because interaction relies on many different semiotic resources, analysis of interactional processes must be sensitive to the social affordances of the specific medium being analyzed, yet also be applicable across multiple media in order to facilitate dialog between researchers. This introduces a pair of related challenges to the creation of a generalizable method: it must be media agnostic but simultaneously media aware. A workable method needs to be independent of the form of the data under analysis. At the same time, the method needs to maintain a record of how people make use of the specific affordances of media. This is required to allow analysis to speak to design and empirically drive the creation of new, more effective media.

Much of the foundational work in sequential analysis of interaction has focused on face-to-face interaction. Production blocking and the ephemerality of spoken interactions constrain communication in such a manner that turns (Sacks et al., 1974) and adjacency pairs (Schegloff & Sacks, 1973) are appropriate units of analysis for face-to-face data. These units of analysis are not as appropriate for CMC since most online media support simultaneous production and persistence of contributions. Contributions may become available to other participants in unpredictable orders, may not be immediately available, and may address earlier contributions at any time (Garcia & Jacobs, 1999; Herring, 1999). Because conceptual coherence can be decoupled from temporal or spatial adjacency, we cannot restrict analysis to the relationships between adjacent events. Nor is it appropriate to treat CMC as a degenerate form of face-to-face interaction (e.g., by seeking an analog to adjacency pairs) since people use attributes of new media to create new forms of interaction (Dwyer & Suthers, 2006; Herring, 1999).

Based on considerations discussed in this section, we sought an analytic approach that (1) maintains the sequential and situational context of activity so that an account of the interactional construction of meaning is possible, (2) does not assume that the medium of interaction has any particular interactional properties (e.g., synchronicity, availability of contributions, or persistence), but (3) records these properties where they exist. Additionally, it should (4) be sufficiently formalized to enable computational support for analysis, including sequential and statistical analysis, and (5) capture aspects of interaction that are critical to learning. The analytic framework we developed draws on other interaction analysis methods, but it uses generalized concepts of interaction elements and structures that are independent of any particular medium. The remainder of the paper describes the theoretical foundations for our analytic representation, and how it is constructed and used.

Theoretical Foundations

We need a unit of interaction that abstracts from media-specific concepts such as adjacency, is applicable to the wide variety of temporal, spatial and notational properties of media, and is capable of tracing the entwinement of individual and intersubjective trajectories of meaning-making. Since collaborative learning is only possible when something is shared and transformed between participants, we built this unit of analysis on the concept of *uptake* (Suthers, 2006a). Uptake is how we describe the act of a participant taking reifications of prior or ongoing participation (e.g., expressions of information, attitudes and attentional orientation; whether ephemeral or persistent) as having certain relevance for further participation. Uptake is a transitive act, in that it always is oriented towards the taken-up as its object, which is foregrounded by the act as being relevant. Uptake is interpretative: some particular aspect of the object is brought forth and given (further) meaning. The "thematic connections" of Resnick, Salmon, Zeitz, Wathen, & Holowchak (1993) are an example of uptake, although our conception allows for nonlinguistic forms of expression, and for other kinds of interpretative acts in addition to argumentative ones. A participant can take up one's own prior reifications as well as those of others: by identifying both, analysts can characterize visible trajectories of intrasubjective and intersubjective meaning-making. Uptake is a form of participation: the act must be visible within a given realm of participation to be uptake in that realm. An individual working through ideas via mental processes and external notations has access to his or her uptake across as well as within these media, but in the social realm only visible acts can foreground and interpret prior reifications.

Our framework for uptake analysis tries to be useful to multiple theoretical and analytic paradigms, but is based on two theoretical assumptions about the nature of artifact-mediated collaborative interaction.

- *Coordination:* Efforts to coordinate between the personal and social realms are enacted through media (including *expressions* and *perceptions*).
- *Ongoing sequential structure:* The sequential structure of these coordinations at successively overlapping and expansive granularities is significant in understanding how meaning-making is accomplished.

All interaction is mediated by physical and cultural tools (Wertsch, 1998), whether in ephemeral media such as thought, speech and gesture, or persistent media such as writing, diagrams, or electronic representations. Distributed cognition (Hutchins, 1995) describes how information is transformed as it propagates via *coordinations* of representations through a distributed socio-technical system. According to Hutchins, the coordinated representations include individuals' internal conceptions in addition to external, perceptible representations. We draw on the idea of coordination, noting that coordination between personal and social realms can be accepted regardless of whether one accepts the existence of cognitive representations. A typical distributed cognition analysis starts by identifying a system's function (e.g., steering a ship) and involves tracing the propagation of information through the system and identifying transformations that take place at points of coordination between the participants and external representations. In settings fundamentally concerned with the creation of new knowledge, this focus on the enactment of functional relationships implies too static an interaction structure, and indeed takes as a starting point that which analysis seeks to uncover. An analysis based on uptake, in contrast, starts with the identification of acts of coordination and the dependencies between them, and seeks to recognize what is accomplished through the interaction. In doing so, we draw on the ethnomethodological idea that the meanings of actions are indexical (deeply tied to the time and place of their enactment), and the consequence that the sequential structure of activity is of fundamental importance (Garfinkel, 1967; Koschmann et al., 2004).

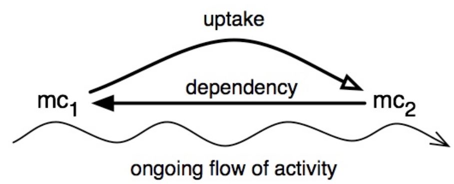

Figure 1. Schema for a dependency

Motivated by the need for a common transcript representation that exposes interactional structures in diverse forms of mediated interaction, and for a formal structure that is amenable to computation, we developed the *dependency graph*. A schema for the basic analytical elements is shown in Figure 1. Any empirical analysis must be built upon observable events. We assume that an analyst is interested in deliberate acts, not just any physical event. Therefore the analyst will examine the ongoing stream of events and identify those that appear to be coordinations between the personal and public realms. These *media coordinations* are exemplified by mc_1 and mc_2 in Figure 1. The existence of conceptions is implied by media coordinations, but we need not (yet) identify these conceptions (see Suthers, Dwyer et al., 2007 for further discussion of implied conceptions). The analyst need only make a commitment that certain coordinations are of interest.

If a media coordination mc_2 is to be understood as taking up the contribution of a prior coordination mc_1, then there must be some observable relationship between the media coordinations. Therefore, we further ground the uptake analysis in empirical evidence by identifying *dependencies* between media coordinations that suggest that there is uptake. Dependencies can be found in media-level, representational, and semantic relationships between media coordinations: these will be discussed below. The dependency graph representation takes the form of a directed acyclic graph consisting of media coordinations and the dependencies between them (see Suthers, 2006a for a formal definition) on which we may layer analytic interpretations. Dependencies provide evidence that uptake may exist, but not all dependencies as defined at the media level need be uptake. The distinction between dependencies and uptake is made because dependencies reflect the myriad of ways in which human action is deeply embedded in and sensitive to the environment and immediate history of interaction, while only some of these relationships enter into the realm of meaning in which participants are demonstrably oriented towards reifications as having relevance for ongoing participation. Once these relationships have been identified, the graph defined by reversing the arcs may be properly called an *uptake graph,* as in (Suthers, 2006a).

Although we have described uptake as something that participants do, uptake is more accurately understood as an etic abstraction that we as analysts use to identify interactionally significant relationships between acts. From an emic perspective, participants don't engage in the abstract act of uptake; they engage in specific acts that they affirm (through subsequent activity) as the accomplishment of recognizable activity (Garfinkel, 1967). The analyst's identification of uptake is a bridge between empirical dependencies and further analysis. Uptake analysis is a proto-analytic method that must be completed by further analysis motivated by a given research program. The dependency graph provides resources for this further analysis by offering potential instances of uptake and grounding analysis in empirical media coordinations. This representation can support multiple methods of analysis, is amenable to computational support and visualization, and is meant as a boundary object for discussion and collaboration across different analytical traditions.

Uptake Analysis

This section describes the practical tasks involved in producing and interpreting a dependency graph, accompanied by a discussion of related issues and concrete examples from our analysis work. In practice, the process may iterate between identification of media coordinations, dependencies, and uptake; and may be driven by specific analytic goals or may be more exploratory in nature.

Identifying Media Coordinations

A dependency graph is built on observed media coordinations for which conceptual or interactional significance is claimed. Media coordinations are a more general form of elements from other analytical methods. Content analysis methods that work with text highlight and code elements in the text record. Conversation analysis and video-based micro-analysis identify points of interest in the media recording or transcript, and the media or transcript may be similarly coded or annotated. The analyst's identifications of media coordinations fulfill the same function as these annotations. Media coordinations are represented as vertices in the dependency graph. We call these vertices *fixed points* since they constitute the points of departure for analysis. Fixed points are anchored in media coordinations that can vary in granularity from a single instant to a period of time. The fixed point's anchor should be specific enough to allow the analyst to return to the media action as accounted in the data record. As in most interaction analysis methods, the source data is always the final authority.

Some media coordinations are easy to identify. When analyzing spoken conversation or CMC, utterances and messages are obvious candidates for media coordinations. The creation of an object in a shared workspace is similarly easy to identify as a media coordination. We use the general term *expressions* to refer to media coordinations of this nature. Other media coordinations are less obvious. For example, if two items are placed near each other in a workspace this may be an expression of relatedness (Dwyer & Suthers, 2006). This illustrates the more general issue of not confusing the representational vocabulary of a medium with the actions supported by the medium. For example, a medium that supports spatial positioning may be used to create groups even if no explicit grouping tool is provided.

Perceptions (e.g., hearing or reading another's expression) are another form of coordination between representation and conception. Explicit identification of perception is absent from many other analysis methods, which implicitly assume that each participant perceives every contribution, and does so at the time that it is produced or displayed. With asynchronous data this assumption is clearly untenable. The applicability of this assumption to synchronous interaction can also be questioned. Therefore our abstract transcript representation allows for explicit specification of evidence for perceptions as another form of media coordination. It is difficult to identify the conception that results from a perception, but it is sufficient to assume that *some* conception results and mark the perception event as a media coordination. Researchers interested only in public behavior need not go further than to use the perceptual media coordination to narrow the temporal scope of uptake of the perceived contribution. Researchers interested in psychological (e.g., cognitive) claims about individual learning may subsequently attempt to infer the conception based on other evidence, including dependency relations. In either case, the observed evidence for perceptual coordinations has been made explicit.

A fixed point is incomplete without a description of the evidence on which the analyst based its identification. The practice of making evidence explicit addresses several issues. It limits the degree to which analysts can make assumptions about media coordinations. For example, maintaining the distinction between expression and perception has forced us to question our assumptions about which contributions are available to others. Specifying the evidence distinguishes the descriptive "what" of the interaction from the explanatory "why" of the analyst's interpretation, making clear the specific details that were seen as significant. This helps multiple analysts collaboratively review their observations and interpretations and facilitates trans-disciplinary discussions.

Identifying Dependencies

The second task in constructing a dependency graph is to identify and document the dependencies between media coordinations. A dependency represents a grounded assertion that the media coordination identified by one fixed point enables the media coordination identified by another fixed point. Dependencies map out the sequential unfolding of the interaction. They are defined in terms of a set of participating media coordinations and grounded evidence for their interdependencies.

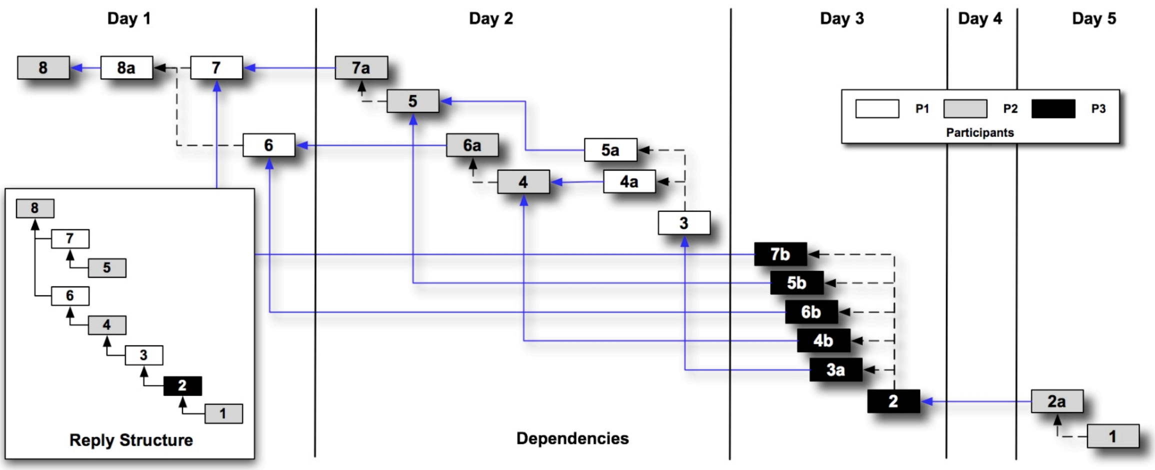

Figure 2. Comparison of threaded discussion reply structure (inset) and dependency graph (main graph) from an online discussion. Fixed points without letters are evidenced by message postings and with letters are evidenced by message reads. Dashed lines represent dependencies for intrasubjective uptake.

Two or more media coordinations can participate in a dependency relationship. Dependencies are directional and point backwards in time. A dependency expresses how a single media coordination depends on *one or more* prior media coordinations. If multiple coordinations are dependent on a single coordination, then multiple dependencies are specified. If mc_2 depends on mc_1 then we are claiming that mc_1 enabled mc_2, but there is no assertion that mc_1 caused mc_2. In our work we have frequently had to work with the ambiguity of "potential dependencies". Dependencies are a generalization of relationship types from other sequential data analysis methods, such as "adjacency pairs," "reply," "thematic connections," etc., and are candidate uptakes. Specifying the evidence for the dependencies serves the same purpose as for the fixed points. In particular, explicit examination of the evidence makes it easier to distinguish the assertion of the dependency from its interpretation. In contrast, in many coding methods the analyst simply asserts an interpretation, e.g., that a contribution is an "elaboration" on or "objection" to another, and the validity of this interpretation is established through computations of inter-rater reliability that do not make the evidence explicit. With dependencies, the evidence must support the assertion that one or more media coordinations played a role in enabling another media coordination. Some types of evidence are more easily identified than others. We have used three types of evidence for dependencies in our work. Starting with the most concrete they are media dependencies, representational association, and semantic relatedness. These are discussed below along with examples.

The most concrete evidence is in the form of *media dependencies*—one action on the representation could not have taken place in the absence of a previous action. A reply in a threaded discussion depends on the prior existence of the message being replied to, and modifying an element of a shared workspace depends on the previous act of creating the element. However, care must be taken not to fall into the trap of conflating the representational vocabulary with the steps in the interaction. Consider a reply in a threaded discussion. The reply message is dependent on the message being replied to, but in terms of dependencies between coordinations it is more accurate to say that the creation of the reply message is dependent on the author's perception of the message being replied to. Figure 2 (adapted from Suthers, Dwyer et al., 2007) contrasts the reply structure of a short discussion (inset figure) with the dependency structure (including perceptions) from which we inferred uptake (main figure). Nodes with letters such as 8a, 7b, etc. represent media coordinations evidenced by message read events. When these perception-related media coordinations are included, a much different pattern emerges. In particular, participant 3's posting (fixed point 2) is not only related to the single message being replied to, but is the result of a series of reads that encompasses two subthreads of the discussion.

The second type of dependency evidence is *representational association*. The use of similar representational attributes is often used to indicate relatedness (Dwyer & Suthers, 2006). The representations can have similar visual attributes (e.g., color or type face) or they can be grouped together or aligned spatially. Temporal proximity can also indicate relatedness—expressions that follow each other closely are often part of the same exchange. Each of these indications of relatedness can imply a dependency. In Figure 2, temporal proximity is part

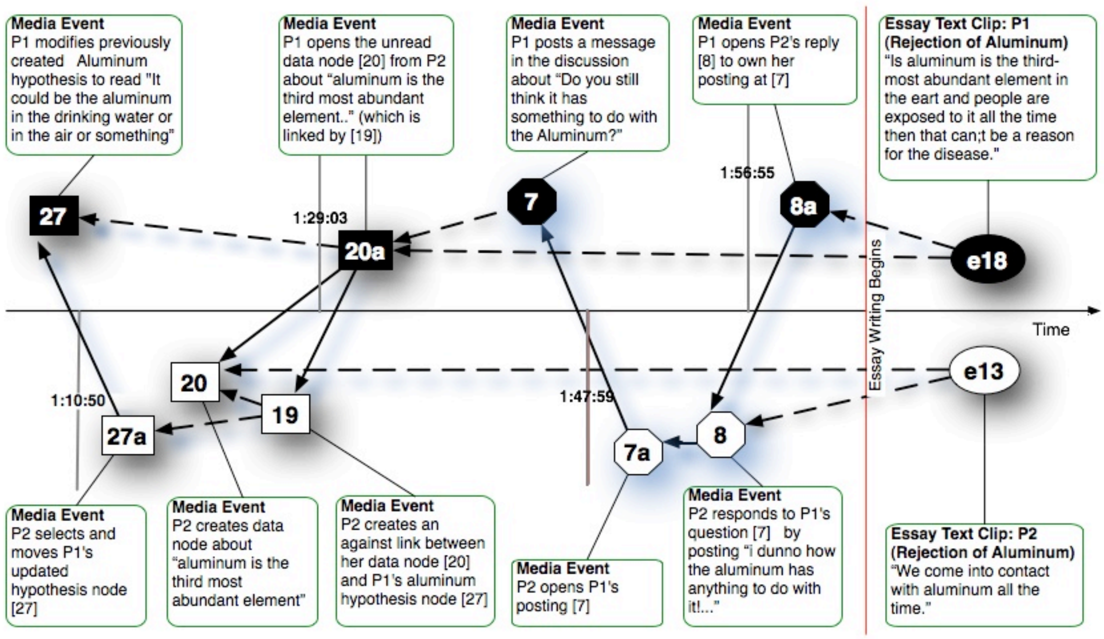

Figure 3. Dependency graph of a dyad collaborating asynchronously with multiple media. Participant 1's coordinations are above and Participant 2's coordinations are below the timeline. Vertical bars represent workspace synchronizations in which the partner's recent work became available. Rectangles, octagons, and ellipses represent coordinations with an evidence map, a threaded discussion, and a word processing tool, respectively. The graph is partial and was constructed by identifying dependencies backwards from the portions of the essays shown.

of our evidence for the dependency of 2 on 7b, 5b, 6b, 4b, and 3a. In Figure 3 (an analysis of collaboration through a shared workspace to be discussed below), spatial connectivity is our evidence for the dependency of perception 20a on 19. Representational association can also consist of repeated words and phrases indicating a dependency on the media coordination in which they were introduced. This can sometimes be easy to identify, for example when copy and paste is observed, or a phrase is typed soon after reading it. However, in general it may be more difficult to identify the original source of any content or to determine whether or not its re-use is actually dependent on the prior use.

The final type of evidence is *semantic relatedness*: the semantic content of a media coordination can be traced to the semantic content of another media coordination. See for example the dependency of 7 on 20a in Figure 3. Semantic dependency can be difficult to identify and is often open to debate. For example, in one case we looked at, one participant added three related nodes to an evidence map. The other participant, after reading them, added a fourth node that seemed to summarize the first three. In general, representational and semantic dependencies are more convincing if convergent evidence exists (e.g., temporal proximity *and* semantic relatedness).

Documenting other media elements

A dependency graph is a partial transcription of an interaction. It may be necessary to record additional information to contextualize the interaction. This additional information can annotate or augment the dependency graph formalism. For example, the reply structure of a threaded discussion is an important resource for understanding the participants' view of the medium, and so is included in Figure 2. In (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2007), we used an asynchronous protocol. In order to identify which representational elements each participant had available at any point in time, we incorporated indications of workspace updates by which participants received new data from their partner, visualized as vertical bars in Figure 3.

Iteration

Production of the dependency graph is an iterative process of densification: multiple passes through the data identify additional elements and provide new insights into the interaction. The formalism of the dependency graph provides support for this process. New fixed points and dependencies can be continually added to the graph. This has the following ramifications. The graph can grow in complexity to reflect a deepening knowledge of the data, but the graph can never be considered "complete," except with regard to particular representational elements (e.g., it is possible to claim that every discussion posting has been recorded as a fixed point). Therefore, one must be cautious about asserting that a practice or pattern never occurs. The quality of the analysis is proportional to the richness of the data. In our work with threaded discussions for online courses we only have log entries for when a message was created and when a user opened a message. Other media coordinations such as scrolling are not logged. On the other hand, our experimental configuration provides a complete record of every mouse and keyboard event, every action on the shared representation, and a video capture of the computer screen from each client. The richness of the latter data has allowed us to examine interaction at a much finer grain. Nonetheless, the threaded discussion data is sufficient for coarser grained analysis. Finally, repeated iterations may identify new *types* of representational elements, media coordinatins, and dependencies. Our work has suggested two other constructions: interactionally defined representational elements that do not correspond to any explicit representational notation, and composite media coordinations in which two or more media events seem to share a conception.

Example of Discovery by Uptake Analysis

Figure 3 presents a dependency graph of data from a study of collaborative argumentation with evidence maps. See (Suthers, Vatrapu et al., 2007) in this volume for details of the study. This analysis was done to understand how two participants used media resources to converge on the conclusion that aluminum is probably not the cause of a disease under consideration. (The relevant information had been distributed across participants in a hidden profile.) See (Suthers, Medina, Vatrapu, & Dwyer, 2007) in this volume for discussion of whether convergence is achieved by information sharing alone or whether interactional "round trips" are required. Construction of the dependency graph allowed us to discover an interesting interactional pattern that goes beyond simple round trips. The information that "aluminum is the third most abundant element" and that this contradicts aluminum as a causal agent has been successfully shared in an evidence map (media coordinations 27, 27a, 20, 19 and 20a). From an information sharing perspective, this sequence is sufficient to explain the fact that both the participants mentioned the abundance of aluminum (the successfully shared information) in rejecting aluminum as a disease factor. However, participants did another round trip for confirmation over 20 minutes later in the session (7-7a-8-8a). By exposing this dual round trip structure, the uptake analysis enabled us to hypothesize an interactional pattern in which information is first shared in one exchange, and then agreement on a joint interpretation of this information is accomplished in a second exchange. The analysis also helped us discover that participants accomplished the second confirmation round trip by moving to a different interactional medium, the threaded discussion.

We are often asked how long an analysis takes, and what tools we used. Time estimates that are predictive of future work are not yet possible, because the analyses reported in this paper took place concurrently with extensive discussions in which we developed the theoretical and practical basis for the framework. These discussions took place over many months with multiple revisions of the analyses. Visualizations of dependency graphs were constructed using standard tools such as Excel™, Visio™, and Omnigraffle™. Software tools tailored to this task will support more efficient analysis.

Discussion

The initial motivation for developing the dependency graph formalism was to support our analysis of collaborative knowledge construction through computer media (Suthers, 2006a). As this work progressed, we removed implicit assumptions about synchronicity and availability of contributions from the notation. We also realized that we could use the dependency graph as a boundary object between our different analysis methods. We used the dependency graph both to create aggregate statistics of interactions and their relationship to the media (Suthers, Vatrapu et al., 2007), and to examine the sequential structure of interaction (Suthers, Dwyer et al., 2007). The graph allowed us to trace asynchronous interaction between pairs of participants back from aspects of their essays that we wanted to explain. Our most recent analysis of the data (Suthers, Medina et al., 2007) bridged statistical and sequential approaches by algorithmically identifying instances of an interaction pattern we refer to as a "round trip" and then applying statistical tests on their frequency across experimental conditions.

There are multiple benefits to the dependency graph as a transcript notation. First, the notation is independent of the interaction medium and can be applied to face-to-face and online interactions as well as interactions that take place in multiple media. The use of generic media coordinations allows the inclusion of a whole range of communicative actions, including perceptions and interactionally constructed representational elements. The concept of dependency extends the concepts of utterance and adjacency pair to online and asynchronous media and accounts for cases where media coordination is the result of multiple, previous media coordinations. Second, the notation can be used to address the tradeoff between statistical aggregation and sequential analysis described at the beginning of this paper. The dependency structure can be used to document and interpret the sequential structure of the interaction and can also be coded or searched to provide data for statistical analyses. Third, the dependency graph adapts to the density of the source data. High-fidelity data can be used to produce a dense graph that can be subject to detailed analysis. On the other hand, sparse data will produce a sparse graph but will still support limited analysis. Fourth, the graph data structure is open-ended—additional data can always be added, although this does imply that skepticism about the completeness of the graph should be maintained. Fifth, grounding in explicit media coordinations allows analysis of correlations between interaction patterns and the media affordances that shape them. Finally, the formalism of the graph structure supports building tools to manage its complexity and is amenable to algorithmic analysis and data mining techniques.

A delimitation of the framework is that, in focusing on observed interaction, it does not explicitly acknowledge the cultural or historical situatedness of the participants, or address identity and community, except where these constructs might be recorded in terms of prior interaction. Many theoretical and practical issues remain to be worked out. A pressing task is to extend the dependency graph formalism to better incorporate composite media coordinations and the possible ambiguity of dependencies. A complete explication of these two items is necessary to extend the potential algorithmic support provided by the dependency graph structure. The greatest practical need is to develop software tools to help construct and use the dependency graph. The need for improved analysis tools is a recurring theme (Sanderson & Fisher, 1994), and the size and density of the potential data sets exacerbates this need. Elaborations on the visual representation should be explored, including embedding dependency graphs in a CORDTRA-style representation (Hmelo-Silver, 2003) to relate interaction to both media and episodes of activity. An important aspect of evaluating this framework will be to determine how well it scales to the types of interactions and media that are of most interest, including larger groups across longer time scales. Manual identification of media coordinations and dependencies is time-consuming at present, but with improved automation it might be possible to generate dependency graphs for larger online communities over the course of months or even years. Finally, the value of this framework in supporting multiple analytic traditions and producing “boundary objects” for CSCL research can only be realized in collaboration with other laboratories undertaking analysis of collaborative interaction.

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Acknowledgments

This work was supported by the National Science Foundation under CAREER award 0093505.

Conceptual Representations Enhance Knowledge Construction in Asynchronous Collaboration

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Abstract: An experimental study of asynchronously communicating dyads tested the claim that conceptual representations could more effectively support collaborative knowledge construction in online learning than threaded discussions. Results showed that users of conceptual representations created more hypotheses earlier in the experimental sessions and elaborated on hypotheses more than users of threaded discussions. Participants using conceptual representations were more likely to converge on the same conclusion and scored higher on post-test questions that required integration of information distributed across dyads in a hidden profile design. However, the essay contents and post-test offered no evidence for differences in information sharing in itself. These results were most consistent when a knowledge map with embedded notes was the primary means of interaction rather than when it augmented a threaded discussion.

Introduction

Prior work has established the potential value of representational guidance for social processes of learning (Dillenbourg, 2005; Suthers & Hundhausen, 2003). Research on representations that are constructed by learners during collaboration (Suthers & Hundhausen, 2003) and representations used as a discussion medium (Baker & Lund, 1996; Guzdial & Hmelo, 1997) has shown that the choice of representation can change the focus of learning discourse. Research on computer-mediated communication (CMC) has identified problems as well as opportunities related to typical representations through which people communicate online (e.g, threaded discussion and chat). Although discussion forums may support more reflective contributions (Hawkes & Romiszowski, 2001), online interaction can also suffer from *incoherence* due to the violation of adjacency conventions for topic maintenance (Herring, 1999) and the coarse granularity of referencing (Reyes & Tchounikine, 2003). Furthermore, there can be a *lack of convergence* due to the intrinsically divergent representations used in threaded discussion (Hewitt, 2001) and a bias towards addressing recently posted messages (Hewitt, 2003). The shared knowledge being constructed is not made explicit by typical CMC tools, and hence it is difficult to find relevant contributions, place one's own contribution in the relevant context, or quickly assess the outcome of the discussion (Suthers, 2001; Turoff, Hiltz, Bieber, Fjermestad, & Rana, 1999).

Suthers (2001) argued that if the conceptual development of the conversation can be made explicit and each contribution to the discussion can be referenced to a component of this conceptual representation, coherence may improve because the conceptual relevance of each contribution is clear (see also van der Pol, Admiraal, & Simons, 2006), and convergence may improve because multiple contributions referencing a given topic are collected together. The present study constitutes an experimental test of these ideas, conducted in an asynchronous setting to inform this increasingly prevalent form of online learning (Mayadas, 1997). Participants were enabled to construct explicit representations of the topics and conclusions of their discussion as they interacted. Two forms of conceptually-enhanced support were compared to each other and to a threaded discussion control condition. Below, we first specify our research hypotheses and explain how these are reflected in the software designs that define the experimental treatments. The remaining sections follow the traditional presentation sequence.

Hypotheses

Knowledge construction seeks systematicity, coherence, and convergence as participants engage in meaning-making to extend their understanding (Wells, 1999). Knowledge construction is *elaborative*, because understanding is improved when the implications of an idea are explored; *integrative*, because coherence is improved when connections are formed between distinct elements of one's understanding; and *reflective*, because one must be aware of and assess the state of one's own knowledge to determine where improvements can be sought, and in particular in order to identify opportunities for elaboration and integration. *Collaborative* knowledge construction is accomplished when these processes take place in joint as well as individual acts of meaning-making (Scardamalia & Bereiter, 1994; Stahl, 2006). Our primary hypothesis (H1) claims that *collaborative knowledge construction is more effectively supported by environments that make conceptual objects and relations explicit.* (A visual representation of reply structure, as in CSILE (Scardamalia, 2004), does not meet this definition.) Explicit representations of conceptual structure have the advantages that they encourage participants to clarify their thinking (Brna, Cox, & Good, 2001), make this thinking visible to others (Bell, Davis, & Linn, 1995), provide resources for subsequent conversation (Roschelle, 1996), can guide students' argumentation to include disconfirming as well as confirming evidence (Toth, Suthers, & Lesgold, 2002; Veerman, 2003), and can function as a "convergence artifact" that expresses the group's emerging consensus (Hewitt, 2001; Suthers, 2001). This primary hypothesis does not specify the relationship between knowledge representations and the conversation that accompanies the creation of those representations. Our secondary hypotheses are alternative elaborations of H1, arguing for either maintaining the distinction between discussion and knowledge representations or combining the two.

One could argue that discussion representations should be embedded in or mixed with the conceptual representations to contextualize the discussion and facilitate ease of reference (e.g., by simple attachment of notes to the objects to which they refer). A usability argument can also be made: it may be easier to manage a single workspace than interactions distributed across multiple tools. This reasoning leads to the second hypothesis (H2): *Collaborative knowledge construction is more effectively supported if conversational and conceptual representations are tightly integrated.*

The third hypothesis is motivated by the observation that conversational structures and conceptual structures are different: conversation relies on regularities in adjacency and focus shifts for coherence (Grosz & Sidner, 1986; Sacks, Schegloff, & Jefferson, 1974), while conceptualizations may be organized according to diverse ways of modeling or systematizing knowledge about the world. Therefore, separate tools will enable designers to optimize representations to meet the distinct structural needs of conversation and conceptualization in a given domain of discourse. Explicit referencing can be used to make the connection between the two representations (Mühlpfordt & Wessner, 2005; Suthers, 2001). This reasoning leads us to the third hypothesis H3, which is in opposition to the second: *Collaborative knowledge construction is more effectively supported if the distinction between discussion and conceptual models is reflected in the representations provided.*

Software environments

We constructed three software environments (Figures 1-3) in order to test these hypotheses. All three of the environments have an "information viewer" on the left in which materials relevant to the task are displayed. All three environments have a shared workspace or "information organizer" on the right hand side (and in one case the lower left) in which participants can share information they gather from the problem materials as well as their own interpretations and other ideas. The three environments differ on the nature of the "information organizer," as described below. Changes made to the workspace by each participant are propagated to other participant's displays of the same workspace under an asynchronous protocol to be discussed.

The shared workspace in the *Text* condition is a conventional threaded discussion tool (Figure 1). This is the control condition for testing the above hypotheses, since the workspace only provides explicit support for representation of discussion structure (subject headings and reply relations).

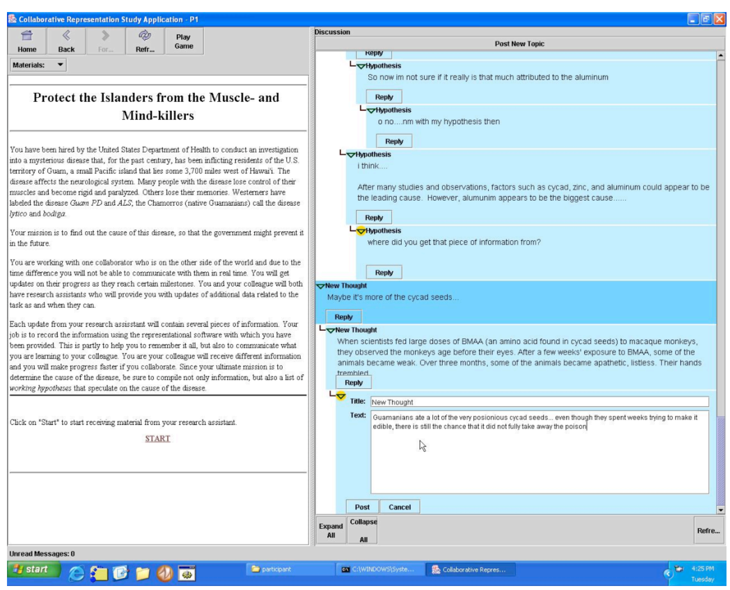

Figure 1. *Text* environment (threaded discussion)

The shared workspace for the *Graph* condition includes tools for constructing conceptual objects under a typology relevant to the task of reasoning about evidence, 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* and *inconsistency* relations between other objects, visualized as green links labeled "+" and red links labeled "-" respectively. "Unspecified" objects and "unknown" links are also provided for flexibility. Finally, a *note* object (lower right of Figure 2) 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 an evidence map and link them like any other object, as suggested by H2. In this paper, we use *evidence map* to refer to the specific representational tool used in the experiment, and *knowledge map* to refer to the category of conceptually explicit representations.

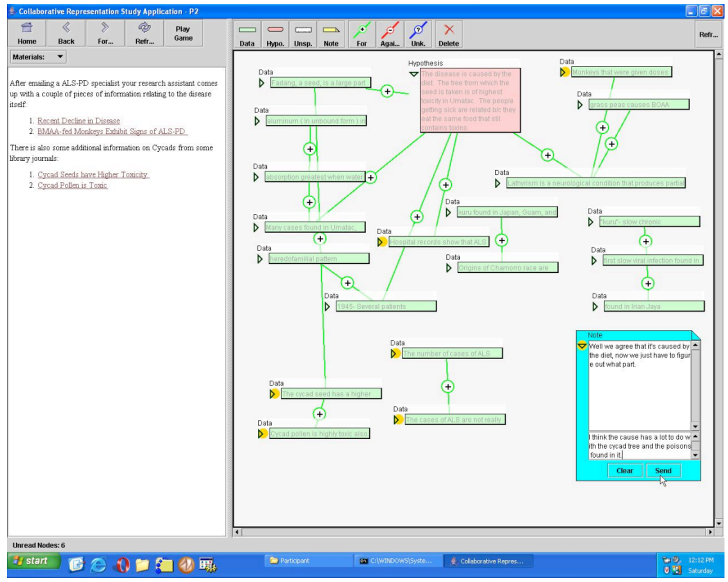

Figure 2. *Graph* environment (knowledge map)

The shared workspace of the *Mixed* condition includes both a threaded discussion tool and an evidence-mapping tool for representing conceptual structure in the same manner as the Graph condition, except that there are no embedded notes in the Mixed version of the evidence map. Instead, one can embed references to evidence map objects in the threaded discussion messages by clicking on the relevant graph object while composing the message. The references show up as small icons in the message (Figure 3). When the reader selects the icon, the corresponding object in the evidence map will be highlighted. This environment is motivated by H3, which claims that separate representations are needed to optimize discussion and conceptual organization.

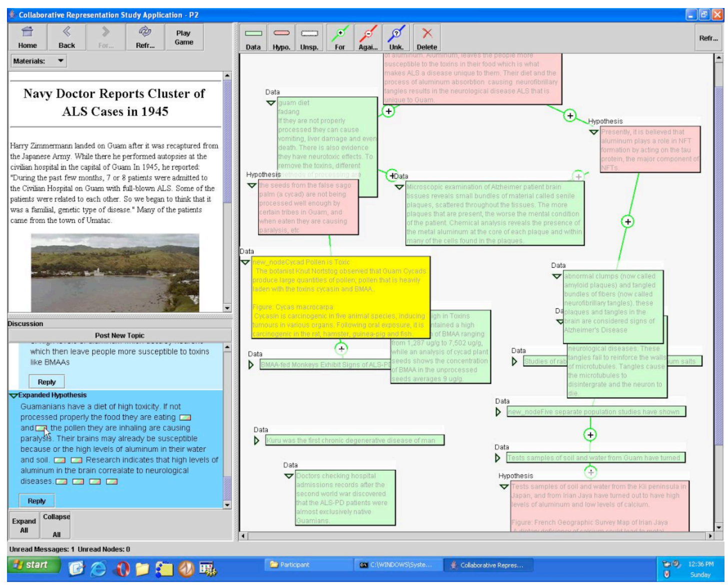

Figure 3. *Mixed* environment (threaded discussion linked to knowledge map)

Methods

This section provides a brief summary of the experimental method. Further details are forthcoming in (Suthers, Vatrapu, Medina, Joseph, & Dwyer, in press).

Design

H1 predicts that the presence of a conceptual representation will be beneficial. However, there are many choices to be made in designing software environments, and we anticipated that the implementation chosen could obscure the viability of H1. Therefore, in order to determine whether *some* implementation of a conceptual representation is better than threaded discussion alone, we test H1 through two sets of comparisons: Text versus Graph and Text versus Mixed. The competing hypotheses H2 and H3 are tested by comparisons of the Graph and Mixed conditions to each other. Planned comparisons on process measures included the number of hypotheses proposed and the extent to which these hypotheses were elaborated on or integrated with evidence. Planned comparisons on outcome measures included the quality of conclusions reached, convergence of participants on the same conclusion, the extent to which participants relied on shared information for their essays, individual memory for different kinds of information, and usability evaluation of the software.

Participants

Pairs of participants were recruited from introductory courses in the College of Natural Sciences at the University of Hawai`i. Participants were paid US$50 each for participating in the experiment. We recruited participants in pairs of acquaintances so as to eliminate the social awkwardness of interaction between persons who do not know each other. Excluding pilot studies, we conducted a total of 30 experimental sessions involving 30 pairs or 60 participants. There were 10 pairs of participants (20 participants) for each of three treatment groups: Text, Graph and Mixed. Conditions were gender-balanced: each treatment group included 4 female-female, 4 female-male and 2 male-male dyads. We verified that there were no statistically significant differences between the three treatment groups on age ($F(2, 54) = 0.18$, $p= 0.8361$) and grade point average ($F(2, 54) = 1.20$, $p= 0.3105$). We also verified through a pre-experiment questionnaire that none of the participants had prior experience with the experimental problem.

Materials

The experiment presented participants with "science challenge" problems, consisting of issues in science and public health. The main problem challenged participants to identify the cause of a disease on the island of Guam known as ALS-PD. This disease has been under investigation for over 60 years, in part because it shares symptoms with Alzheimer's and Parkinson's diseases (Lieberman, 2004). Over the years several hypotheses have been proposed and evaluated with evidence of varying types and quality. 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). These facts along with the relative obscurity of the problem make it a good problem to use when one wants participants to grapple with interpretation of multiple explanations and ambiguous data.

The source materials were divided into twelve (12) sets of materials, each set consisting of a brief introduction and links to four articles. (A complete list of source materials for the ALS-PD problem is available online at http://lilt.ics.hawaii.edu/lilt/papers/2007/Suthers-et-al-CSCL-2007/.) In a given experimental session, each of two participants (designated P1 and P2) was assigned half of these of materials, presented in six "study sessions." Each article typically consisted of one to two brief paragraphs and an image or two. An example article is shown in the left hand side of Figure 3 (shown previously). Each article was designed to provide one key item of information relevant to a hypothesis. The remaining information in a given article elaborated on this item or provided tangentially related "distracter" information. We designed the articles to provide evidence both for (+) and against (-) five major hypotheses (the codes are used in Table 1): (A) aluminum levels in water and soil, (G) genetic causes, (Z) zinc levels in water, (C) consumption of cycad flour, and (B) consumption of fruit-eating bats as a source of the cycad toxin. The articles also included a mission statement and other general information about the disease and its demographics (D).

Table 1: Distribution and sequencing of information articles across participants and study sessions.

Session#	P1's Articles				P2's Articles			
1	A7+	G3-	A1+	A2+	G1+	G2+	C1+	C2+
2	D1	D4	A3+	A5+	D6	C3+	C7+	C8+
3	C1+	B2+	A6+	D2	B1+	B5+	A2-	A1-
4	C6+	D5	C3-	G1-	A3-	Z1+	C5+	Z2+
5	Z1-	G2-	C2-	D3	C10+	C9+	A4-	B4+
6	C5-	B3+	A4+	C4-	C4+	C11+	C1-	Z3+

We used a "hidden profile" (Stasser & Stewart, 1992) in which information is distributed across participants such that a participant relying only on information he or she directly received would come to a suboptimal conclusion. The sequencing of articles was designed to require integration over time, motivating use of the information organizing workspace to make relevant information available in later study sessions. Table 1 shows the complete distribution of materials across the participants. For example, one participant (P1) received evidence for aluminum as a disease agent (A1+ through A7+) and evidence against genetic causes (G1- through G3-), while the other participant (P2) received evidence for genetic causes (G1+ and G2+) and evidence against aluminum (A1- through A4-). Information sharing between participants was required in order for either participant to reject these and other hypotheses and identify the most complex explanation that incorporates the evidence implicating a toxin derived from cycad seeds (C1+ through C11+), but addresses the low toxicity of prepared cycad flour (C2- and C4-) by identifying bats as an alternative vector via which the toxin enters humans (B1+ through B5+). Because of this distribution of information, we can draw conclusions concerning information sharing by eliciting participants' beliefs and evidence for those beliefs at the end of the experimental session.

Procedure

After signing of consent forms and a demographic survey, participants were introduced to the software and format of the study sessions through a standardized set of instructions and demonstrations. Participants were then led to their respective stations in different rooms from each other, and worked for up to 30 minutes on a "warm-up" problem to familiarize themselves with the software. Then participants were given up to 120 minutes to work on the main problem, Guam ALS-PD. All six study sessions were completed within this time period.

In order to inform online learning, we designed an asynchronous communication protocol that enabled us to conduct experimental sessions with participants in the laboratory. The fundamental criterion was that there be no particular timing constraint between the actions of participants (e.g., waiting for the participant's action before being able to continue one's own work), nor temporal affordances to be exploited in a synchronous manner (e.g., sending a message and expecting an immediate reply). A second aspect of asynchronous work that we sought to simulate is that one might stop working on a problem for a while, do something else, and then return to the work. We achieved these desiderata through a protocol in which (1) participants took occasional "breaks" from their work to play a computer game, Tetris™, and (2) the work of the other participant became available only after these breaks. In each study session, participants were expected to read the four articles and update the shared workspace as they deemed appropriate. Tetris™ was chosen for its familiarity and because it presents a perceptual motor activity quite different from the cognitive task of the experiment, in this sense constituting a break from the primary task.

At the conclusion of their final study session, each participant working alone 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 online environment remained available to each participant during the essay writing, but there was no further communication between participants. All participants were able to complete their essays in this time period. One week after the experimental session, each participant was required to complete an online post-test (described below) before payment was sent.

Data collection

Demographic information was collected through a survey and by obtaining Scholastic Aptitude Test (SAT) scores and Grade Point Averages (GPA) (with participants' permission). Process data was collected through two primary means. First, the Morae™ recording software was used to capture the computer screen in digital video. Second, our software was designed to generate complete logs of all the events at each client workstation. Post-session data included the essay and the usability questionnaire elicited immediately after the experimental session, and the post-test elicited one week later.

The post-test was a 20-item 6-choice objective question and answer instrument based on information contained in the ALS-PD articles. The post-test contained two classes of multiple-choice questions. *Memory* questions could be answered based purely on distracter information that was presented in a single article to a single participant. Since only one participant received the distracter information, half of the memory questions were based on information presented to P1 and half on information presented to P2, enabling us to test for adequate information sharing. *Integrative* questions could only be answered by integrating information that was distributed across articles and participants but in combination suggested a cause of the medical condition. Integrative questions were further divided: *high integration* questions required integration of information presented 5 or more study sessions apart (the "inferential span" of Suthers & Hundhausen, 2003). The test design allows us to separate out evidence for information sharing from evidence of integrative elaboration. H1 predicts that a difference will be found on the integration questions in favor of the conditions provided with evidence maps, but not necessarily on the memory questions, as they depend only on information sharing, which can just as well be done in any unstructured but persistent messaging medium.

Results

Our analyses addressed *outcomes,* based on content analyses of the essays and scoring of the post-test; and *session processes,* based on quantitative analyses of elaboration on hypotheses. Due to space constraints, ANOVA tables are omitted. Tables may be found in (Suthers et al., in press), although the present paper contains further interpretations. The traditional criterion of $\alpha \leq 0.05$ is used for statistics computed to test hypotheses. However, we view probabilities as properties of the data to be reasoned about, not merely as input to a mechanical binary decision procedure (Gigerenzer, 2004). Therefore we report *p* values of 0.1 and below as indicative of phenomena worthy of further investigation.

Outcomes analyses

Content analysis of individually written essays examined both participant's conclusions (disease hypotheses), and the facts participants cited from the information we provided, with particular attention to evidence for sharing of information given to only one participant.

We coded each participant's essay for information that was provided by the source materials. The point of this coding was to trace out ideas that came from the source materials. Therefore, the coding units were based on information as it was expressed in sentences and figures of the source materials. Two analysts independently carried out the analysis and conflicts were resolved by consensus. The counts are presented in Table 2, factored in three ways for the following tests. (1) As a baseline, we wanted to determine whether the treatment groups differed on the amount of information participants collectively expressed in their essays, and on the source of that information (from materials given to P1 versus materials given to P2). We conducted a post-hoc two-way analysis of variance (ANOVA) between the three conditions (Text, Mixed and Graph) and the two sources of materials (given to P1 and to P1), testing for an interaction effect. The dependent variable was the amount of information cited in each participant's individually written essay. The difference was not significant. (2) A follow-up one-way ANOVA did not indicate significant differences across the three conditions on participant's preference for facts from their own materials versus others'. (3) We then wanted to see whether there was a difference between the three conditions in the amount of information cited by *both* P1 and P2 in the individually written essays. The follow-up one-way ANOVA was not significant by the criterion of $\alpha \leq 0.05$, but can be interpreted as being consistent with greater overlap in Text ($F(2,27)=2.82$, $p=0.0771$).

Table 2: Mean counts of information units in the essays (columns denote source materials)

(1) Information units in P1 or P2's essays			
	From P1	From P2	Total
Text	6.7	8.25	14.95
Graph	6.3	5.95	12.25
Mixed	6.35	6.4	12.75

(2) Breakdown of (1) for individual essays			
	From P1	From P2	Total
Text P1	7.5	8.2	15.7
Text P2	5.9	8.3	14.2
Graph P1	7.3	4.6	11.9
Graph P2	5.3	7.3	12.6
Mixed P1	7.8	5.7	13.5
Mixed P2	4.9	7.1	12

(3) Information units in both P1 *and* P2's essays			
	From P1	From P2	Total
Text	2.5	3.4	5.9
Graph	2.1	1.6	3.7
Mixed	1.1	2	3.1

We also examined the conclusions provided in the essays in response to the instructions: "Write a concluding paragraph in which you identify one or more hypotheses that you believe are *best* supported by the evidence". Two analysts conducted this analysis, obtained similar results, and selected a final analysis by consensus. Participant's conclusions were assessed on differences in *convergence*, as measured by whether each pair's individual essays agree on the cause for the disease (the maximum possible is 10 pairs per condition), and *quality of solution*, as measured by whether individuals identified the most encompassing explanation, namely that the bats were the vector introducing the toxin from cycads into people (the maximum possible is 20 individuals per condition). The results from this analysis are shown in Table 3. There are clear differences between treatment groups in pair agreement, with greater convergence in the Graph condition (χ^2 (2, N=30)=7.5, $p \leq 0.025$). From the standpoint of quality of solution (under an admittedly simple measure), the difference is decidedly not significant, in spite of the appearance of a trend in the table.

Table 3: Conclusions selected in essays

	Convergence *	Quality
Text	4/10	5/20
Graph	8/10	2/20
Mixed	2/10	2/20

Recall that the *post-test* included both memory and integrative questions. No significant differences were found in total scores (combining memory and integration questions) across conditions. Comparison of participants' performance on memory for one's own information versus memory for information given to one's partner yielded no significant difference. Therefore, the post-test results provide no evidence for differences between the software conditions in terms of either individual memory or information sharing between participants. However, a difference was found on high (but not low) integration questions—those questions requiring integration of information across a span of 5 or more study sessions ($F(2,57)=4.40$, $p=0.0167$). A Bonferroni 95% CI indicated that Graph participants performed better than Mixed participants.

Process analysis of study session data

Analyses of the study sessions themselves enable us to identify possible explanations for the outcome differences. Although most of these quantitative analyses were planned, exploratory examination of the session logs led to an unplanned quantitative analysis. In the Graph and Mixed conditions, participants considered the first hypothesis much earlier than in the Text condition. Also, there seemed to be little discussion in the Text condition compared to the other two. These observations prompted us to conduct a quantitative analysis of the time to create the first hypothesis, in addition to planned analyses of elaboration on hypotheses.

A post-hoc test of the *time to consider the first hypothesis* measured the time in seconds for each individual participant to introduce the first hypothesis in any medium. A one-way ANOVA conducted on the time in seconds taken to create the first hypothesis yielded significant results ($F(2,57)=10.14$, $p=.0002$). Graph had the earliest creation of the first hypothesis, measured in seconds from the start of the first ALS-PD study session ($M=618$, $SD=568.9$) The Mixed condition was ranked next (M=1162, $SD=1244.3$) as compared to the Text condition ($M=2433$, $SD=1807.7$). A Bonferroni 95% CI showed that the differences lie between Text and Graph, and between Text and Mixed.

H1 predicted that collaborative knowledge construction is more effectively supported by environments that make conceptual relations explicit, because knowledge construction is a process of elaboration and integration that requires awareness of one's own conceptual understanding (i.e., is reflective). An analysis of elaboration and integration was undertaken to test this prediction. For purposes of this analysis, *elaboration* is defined to include any action that explicitly considered an already created hypothesis, for example by rewording the hypothesis, discussing the implications of the hypothesis, or providing evidence in support of or against the hypothesis. The analysis encompassed both the contents of linguistic expressions and manipulations of the evidence map, if present. Two coders performed the analysis independently and then the final results were arrived at by consensus.

A one-way ANOVA of the *total elaborations* on hypotheses revealed significant differences between the groups ($F(2, 57)=13.59$, $p<0.0001$). There were more elaboration acts in the two treatment conditions that offer an evidence mapping tool: both Graph ($M=17.90$, $SD=13.74$) and Mixed ($M = 12.85$, $SD=7.05$) had considerably more elaborative acts than Text ($M=3.25$, $SD=2.45$). A one-way ANOVA of the *number of hypothesis expressed* revealed significant differences between the treatment groups ($F(2, 57)=4.73$ $p=0.0126$). Participants in Graph expressed significantly more hypotheses ($M=5.7$, $SD=3.1$) than in Text ($M = 3.3$, $SD = 1.7$). As would be expected from these results, a one-way ANOVA of the *average number of elaborations per hypothesis* was significant ($F(2, 57)=6.86$, $p<0.0021$). The differences are between both Graph ($M = 3.785$, $SD = 3.634$) and Mixed ($M = 3.781$, $SD = 2.981$) versus Text ($M = 0.995$, $SD = 0.762$): the presence of an evidence mapping tool results in more elaboration on each idea considered.

Discussion

Two lines of evidence support H1, based on process and outcome data. The process data shows clearly that there was more elaboration on hypotheses in both of the environments that made conceptual objects and relations explicit (Graph and Mixed) as compared to the environment that did not (Text). Hypotheses were stated earlier in the experimental session (i.e., in earlier study sessions) and there was more elaboration on the hypotheses individually as well as collectively. Furthermore, Graph users considered more hypotheses. These results are consistent with the representational guidance effect demonstrated for face-to-face interaction in a laboratory setting by Suthers and Hundhausen (2003) and in a classroom setting by (Toth et al., 2002). See also (Veerman, 2003) for a related study in a synchronous online setting. In summary, process measures suggest that more knowledge construction takes place when interaction is supported by conceptual representations.

Although the process analyses did not specifically consider group processes, the outcome data suggests that there are consequences at the group level. The analysis of solution hypotheses identified in the essays showed that participants in Graph were more likely to converge, expressing the same conclusions in their essays. This convergence cannot be attributed to a paucity of alternatives: the process data shows that Graph users considered *more* hypotheses than the others, which makes their convergence even more notable. The convergence is probably not due to more effective information sharing per se, since there were no differences on number of facts mentioned in the essay (content analysis 1), on whether information given to one participant appeared in the other's essay (content analysis 2), on the information that both participants found worth citing in the essay (content analysis 3), or on memory for information given to one's partner (post-test analysis). A plausible explanation is that the shared and visually oriented evidence mapping workspace (which was available during the essay writing) enables participants to both see the same "big picture" from which they draw the same conclusions while writing the essays—a "group mirror" (Dillenbourg, 2005). This explanation admits the possibility that convergence took place only during essay writing rather than the sessions. Yet, the same evidence mapping workspaces were also shared during the session, so the same argument can be made for the role of the visual workspace in coordinating collaborative activity. Given the process data just reviewed, it is plausible that collaborative consideration of hypotheses *during* the study sessions had an effect on convergence of the participants' conclusions. An experimental study of face-to-face collaboration (Suthers & Hundhausen, 2003) similarly found that the work done with an evidence map representation during study sessions had greater bearing on essay contents than the work done with a matrix or a text representation. The similarity of results is interesting in light of the differences between these studies: in addition to the media difference, Suthers and Hundhausen's participants wrote *collaborative* essays *from memory*.

On the other hand, the lack of differences on quality of solution may be counted as evidence against H1. The slightly greater overlap in Text participant's essay content (which did not reach $\alpha \leq 0.05$ in analysis 3) might reflect the tendency of the Text participants to simply cut and paste entire articles into their text messages and leave discussion for the end. The final set of messages available in the sequential representation might be more likely to be pasted into the essay (a recency bias; Hewitt, 2003). The failure of the Mixed condition in some analyses to display the advantages claimed by H1 may also be considered as evidence against H1, but the dual workspace is a confounding factor, as it requires managing two representations (Ainsworth, Bibby, & Wood, 1998). Participants in the Mixed condition may have converged the least because the dual workspaces provide more variation in strategies for using the workspaces, increasing the possibility that members of a pair will look at different material.

Turning to the comparison between H2 (in favor of integrated representations such as Graph) and H3 (in favor of distinct discussion and conceptual representations such as Mixed), direct differences between Graph and Mixed are limited, the exception being that Graph users remember more integrative relationships than Mixed. Again, the additional complexity of using two representations (the threaded discussion and the evidence map) may have been a factor in Mixed. The distribution of information across two media in Mixed may have posed a barrier to integration of that information, obscuring the advantage of Mixed's evidence map. However, there is indirect evidence bearing on the choice between H2 and H3. All other statistical analyses in which there was a significant advantage for one of the conditions over the others included an advantage of Graph over Text. In contrast, Mixed was sometimes advantageous to Text, sometimes not, but never was advantageous to Graph, and sometimes yielded the worst results. Since Graph and Matrix were introduced as competing alternatives to threaded discussions, support for H2 is stronger than for H3.

Summary and Conclusions

Many tools for online collaborative learning are text based, typically providing representational support only for conversational structure in the form of reply relations (threading) of contributions. Along with others (Turoff et al., 1999), we have argued that tools for online learning should provide representational support for conceptual structure in order to address issues of coherence and convergence and more effectively support collaborative knowledge construction (Suthers, 2001). The experiment described in this paper set out to investigate the claimed merits of conceptually oriented representations and of two approaches to the relationship between conceptual and discussion representations. This experiment was undertaken in an asynchronous setting, using a protocol for practical experimental study of asynchronous collaboration in the laboratory. A representational effect was identified: users of a knowledge representation tool that includes primitives for hypotheses are more likely to state hypotheses early in their experimental sessions, elaborate on these hypotheses and integrate them with data than users of the threaded discussion tool. In the threaded discussion, participants tended to simply record the literal text of the information articles, and not discuss hypotheses until later in the experimental session. Examination of the final conclusions stated in the essays shows that pairs using the evidence map with embedded annotations were more likely to converge on the same hypothesis, even though they had considered more hypotheses and appeared to have access to the same information. Results from a post-test conducted a week later also suggested that embedded conceptual representations improve collaborative integration of information.

There is indirect evidence that the operative mechanism was not differences in information sharing. This evidence is indirect because it is based on outcome data. An analysis that traced out information sharing during the session would provide more direct evidence. Such an analysis has recently been completed, and is reported in a companion paper (Suthers, Medina, Vatrapu, & Dwyer, 2007), because it addresses a distinct research question (comparing models of collaboration rather than software conditions) and relies on a different form of analysis.

The primary finding of this study—that collaborative knowledge construction is fostered by conceptual representations—not only adds to the growing literature on representational guidance for collaborative learning, but also has practical implications. Should threaded discussion tools be replaced with knowledge mapping tools in online learning? Although that is the direction in which the results point, it would be a brash conclusion to draw from this experiment alone, as it is limited in many ways. We studied dyads interacting over a relatively short period of two hours. Dozens of students interacting over the course of a semester (even if divided into smaller groups as is generally recommended in ALN implementations) would generate much more complex artifacts. Any workspace has a limited useful life before it becomes important to "rise above" the clutter and start fresh (Scardamalia, 2004). The subject matter, task structure, and nature of the representations used could also affect results. However, we believe that in conjunction with previous work the present results merit extending the research program beyond the laboratory by undertaking action research in which richer interactive representations are studied in settings of educational practice. Clearly, there are ample opportunities for further research in the "middle space between communication and information interfaces" (Hoadley & Enyedy, 1999).

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Acknowledgments

David Burger and Niels Pinkwart have contributed to the design of this experiment and the implementation of the software on which it is based. Arlene Weiner introduced the first author to the “science challenge problems,” which were reworked substantially for this experiment. This work was supported by the National Science Foundation under CAREER award 0093505.

Information Sharing is Incongruous with Collaborative Convergence: The Case for Interaction

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Abstract: Various authors have placed information sharing at the core of successful collaborative problem solving and learning. In this paper we report analyses of an experimental study that bring the sufficiency of an information sharing account of collaboration into question. One treatment group achieved greater convergence and integration of information in their handling of a complex problem, yet this same group shared *less* information in a hidden profile design. The pattern of convergence is more closely mirrored by *interactivity* quantified as the number of "round trips" addressing the same information items.

Introduction

A central tenet of much research on group problem solving and learning in CSCL and related fields is that information sharing is the primary operative mechanism of effective group performance. For example, contribution theory (Clark & Brennan, 1991) postulates processes by which interlocutors verify that they have successfully shared information. A productive research strategy in social psychology involves the "hidden profile" (Stasser, 1992) in which information is distributed across participants and then group processes are tracked and evaluated in terms of how this information is shared. Common findings include the failure to share information and the failure to use information effectively once it has been shared (Dennis, 1996). In CSCL, Pfister (2005) tells us that "going from unshared to shared information is the gist of cooperative learning," yet Fischer and Mandl (2005) find that the relationship between information sharing during collaboration and individual learning outcomes is not correlative. Their results suggest that information sharing does not sufficiently explain outcome measures of convergence, although differences were seen between factual and "application oriented" information. The present paper also questions the adequacy of information sharing as the basis for understanding collaborative outcomes.

The analyses presented in this paper were motivated by an interesting combination of empirical results obtained in an experimental study that was based on the hidden profile paradigm (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2007). Pairs in one treatment condition performed better on outcomes measures related to collaborative knowledge construction: integration of multiple sources of information and convergence on similar solutions. From this, one would expect that the pairs in this treatment condition also shared more information. Problematically, the treatment conditions did not differ in information sharing as evidenced by the information that participants referenced in their essays, nor on their memory for facts one week later. Those measures of information sharing were based on the products of the experimental sessions (essays and a post-test): more direct measures of information sharing were needed. In the follow-up study summarized in the present paper, we measured the information sharing that took place in the sessions themselves by tracing information that was given to only one or the other participant at the outset. Surprisingly, we found that pairs in the higher performing condition shared *less* information in the session: a serious challenge to the information-sharing explanation of group performance. An alternative explanation was needed, for which we turned to interaction. In information sharing, a participant expresses something in some medium and another participant accesses this expression. The smallest interactional extension of this basic act is a "round trip" of uptake: the second participant takes up that which was expressed by the first participant by forming a new, related expression, which then is accessed by the first participant. Accordingly, we measured interaction in terms of these round trips. By this measure, participants in the higher performing treatment condition (which shared less information) interacted more than participants in the other conditions. The incongruence of the distribution of information sharing together with the congruence of the distribution of round trips suggests that it is worth examining the practices by which participants integrate multiple sources of information and converge on common solutions. This paragraph has outlined the entire argument of the paper. Below we summarize the key analyses before concluding with a brief discussion.

Prior Results on Convergence and Integration

The present paper is concerned with how well information sharing and interaction account for a pattern of results found in a prior study, rather than with the specific question addressed by that study. See the companion paper in this volume (Suthers, Vatrapu et al., 2007) for details. The primary result of interest is that pairs in the Graph condition were more likely to converge on the same conclusion than pairs in the other conditions ($\chi^2(2, N=30)=7.5, p=0.025$): see Figure 1. This suggested that Graph users may have shared more information, but 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. Also, Graph users performed significantly better than Mixed users on the "high integration" questions of the post-test ($F(2,57)=4.40$, $p=0.0167$), suggesting that they were able to more effectively bring relevant and distributed information together. However, comparison of participants' performance on memory for information that they received versus memory for information given to their partners yielded no significant difference, again suggesting that information sharing was not the operative mechanism.

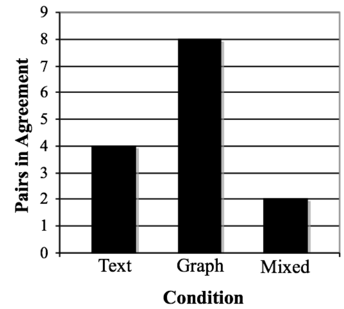

Figure 1. Pair agreement

The Information Sharing Analysis

The essays and post-test are only indirect measures of information sharing. We undertook an analysis to test the possibility that Graph participants achieved integration and convergence by sharing more information *during* the session. This analysis was based on tracing information distributed according to a hidden profile in materials given to participants (Suthers, Vatrapu et al., 2007). An information sharing event consists of the sequence in which (1) P_a (participant A) perceives information that had been given uniquely to him or her, (2) P_a expresses that information in a shared workspace, and (3) P_b (participant B) perceives that expression (objects required a specific action in order to be read). The total number of such events was summed for each pair (the dyad is the unit of all analyses). The 401 information units that were uniquely provided to only one participant define the total number of information sharing events possible under this analysis. Results (Figure 2) show that more *expressions* (2) of the information units and more *perceptions* (3) of these expressed information units were made in the Text condition compared to Mixed and Graph conditions. A one-way ANOVA of perceptions of information units indicates that this data would be highly unlikely if there were no differences on information sharing ($F(2, 27)=13.54$, $p<0.0001$). The difference between Text and Graph falls within a Bonferroni 95% confidence interval. From this analysis, information sharing cannot account for the convergence and integration outcomes. The distributions in Figure 1 and Figure 2 are completely different. It would have been problematic enough if there were no differences between groups, but the result that the Graph users actually shared *fewer* information items than Text users completely invalidates an information sharing account.

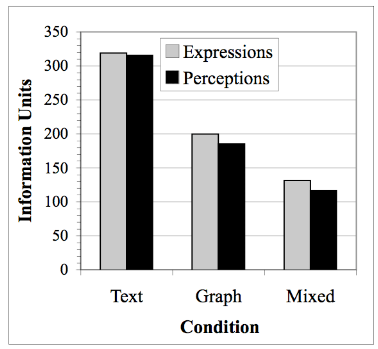

Figure 2. Information sharing

The Round Trip Analysis

Process analyses in the prior study showed that Graph users elaborated on hypotheses significantly more than Text users (Suthers, Vatrapu et al., 2007). Although these analyses counted individual acts in isolation, the results suggest that Graph participants are achieving integration and convergence through continued interaction around previously expressed ideas. "Interaction" is potentially a complex idea: it includes the basic act that we are calling "information sharing" and extends to diverse forms of discourse. To conduct a quantitative analysis we need to identify the simplest possible unit of interaction that is distinguishable from information sharing. Given that we have defined information sharing as including (2) the expression by a participant P_a of an idea related to a topic that is (3) perceived by P_b, the next interactive step that can be taken beyond information sharing is for (4) P_b to express a related idea that is then (5) perceived by P_a. In this "round trip," intersubjectivity forms: P_a has expressed and seen his or her expression interpreted by P_b. In order to place this analysis on the same foundation as the

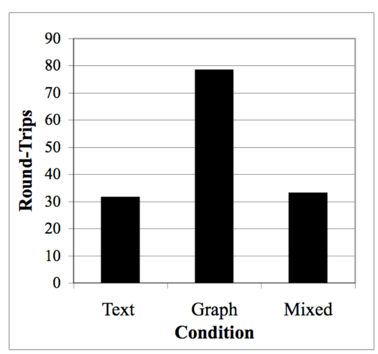

Figure 3. Round trips

information sharing analysis, we decided to include only round trips that involved an information item that was (1) uniquely given to P_a. The results (Figure 3) showed that more round trips were made in the Graph condition compared to Mixed and Text conditions, following the pattern of Figure 1. A one-way ANOVA on number of round trips suggests that these results are not likely if the groups were equivalent on interactivity ($F(2, 27)=3.03$, $p=0.0648$), but pairwise differences did not fall within a Bonferroni 90% confidence interval. This study was limited to tracing round trips addressing factual knowledge: further work could trace the development of hypotheses.

Discussion

This work does not take a stance on whether convergence is desirable. Rather, the point is that a difference in convergence and integration was observed that cannot be accounted for by information sharing, but the simple addition of a reply changes the picture entirely. Although the last test reported does not meet the traditional cutoff of $\propto \leq 0.05$, following Gigerenzer (2004) we view probabilities as properties of the data to be reasoned about in context, rather than as input to a mechanical decision procedure. The combination of results—more elaboration in the graph condition, a pattern of round trips that is unlikely yet congruent with the pattern of convergence we seek to explain, and an incongruent pattern of information sharing—rules out information sharing as an adequate explanation and is sufficient to suggest that interaction is worthy of further study as the basis for knowledge integration and convergence in collaborative learning. Currently, much empirical work in CSCL (as well as some of its sister fields) remains focused on information sharing, while we lack an equally comprehensive research program on whether and how interaction adds value for collaborative learning beyond information sharing. The strategy taken by this paper as a contribution to the ongoing methodological and theoretical dialogues within CSCL is to demonstrate that it may be profitable for those working in an experimental paradigm to examine interaction in order to account for quantitative results. Further, we advocate alliances with those who work in analytic paradigms that delve systematically into interaction (e.g., Stahl, 2007; Suthers, Dwyer, Medina, & Vatrapu, 2007 in this volume). As a topic of study, interaction has potential to unify our field by being the shared object of analysis between researchers in multiple methodological traditions.

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Acknowledgments

David Burger, Sam Joseph and Niels Pinkwart contributed to the design of the prior study on which this study is based. This work was supported by the National Science Foundation under CAREER award 0093505.

Using Learning Management Systems to Support Students' Collaborative Learning in Higher Education

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Abstract: Learning Management Systems (LMS) are web-based systems for the distribution, management and retrieval of course materials, and to support communication between students and instructors. A LMS can also support peer collaboration by providing students with the capacity to create their own project sites. In this paper we present data from system logs, surveys, and interviews to investigate how one such system, CTools, is used by students at a large public university to facilitate peer learning.

Overview

Technology-enabled learning is increasingly important in today's higher education and "courseware" systems appear to be one of the most rapidly diffusing e-learning technologies (Dutton, Cheong, & Park, 2003). Courseware refers to web-based systems that allow instructors and students access to instructional materials, to make class announcements, and to submit, track, and grade student assignments. There are popular commercial products such as WebCT (www.webct.com) and Blackboard (www.blackboard.com), institutionally developed products such as Angel (Penn State, http://ais.its.psu.edu/angel/), and open source products such as Moodle (http://moodle.org) and Sakai (www.sakaiproject.org). A recent report showed that over 90% of all universities and colleges are using one or more courseware-type products for student and faculty use (Hawkins, Rudy, & Nicolich, 2005). In this paper we use the term Learning Management System (LMS) instead of courseware or Course management System (CMS), because the system we study here is employed for learning purposes both inside and outside the course setting.

Early adopters of LMS in higher education have typically come to these applications because they promise to make teaching more efficient. LMS are also being adopted because they are a symbol of innovation and thus create a competitive advantage in the education marketplace and provide opportunities for enabling institutional innovations in learning and education (Dutton, Cheong, & Park, 2003). Although most LMS are used for the distribution, management and retrieval of course materials, these systems are increasingly incorporating functionality that supports communication between students and instructors and among students. Communication tools within LMS provide the kinds of active online engagement preferred by today's generation of students (e.g., discussion tools, chat rooms, wikis, and blogs) and provide opportunities for using these systems according to constructivist approaches to learning rather than simple transmission of knowledge models. In a recent study of WebCT and Blackboard use conducted at Williams, Brandeis, and Wesleyan, more students than faculty reported that the use of these systems "improved learning" (Hanson & Robson, 2004). On our campus, 74% of students felt they learned more from courses when the LMS was used. Our research agenda includes investigating the modes and quality of learning afforded by our LMS.

In this paper we investigate how students use the project site capability of our LMS, CTools, to support working with their peers. Students' perceived value of the LMS has led to a wide proliferation of student-initiated project sites created specifically to support learning activities taking place outside of the classroom and outside of the course website. Students are creating project sites to support the activity of group projects required by courses and for student-led study groups (coined "eProject" and "eTeam" by Dutton, Cheong, & Park, 2003). Providing project space inside the LMS provides students with the convenience of having one integrated environment for both course and project work, and is especially valuable when students find themselves in groups where the members are rarely collocated outside of class time. We are interested in how project sites are used to support collaboration, looking specifically to see how project sites may support peer learning beyond making group work more efficient.

In this paper we use a variety of empirical methods to gain a systematic understanding of how project sites are being used by students to support their own learning. We begin by characterizing the use of CTools for student projects using an analysis of log data from our system. Second, we examine data from an annual web-based survey to see how the use of project tools affects students' perceptions about project work and their own learning. Finally, we report on work in progress consisting of a survey of student project site users and in-depth case studies to illustrate the types of students' project site use.

CTools Use on Campus

Our university has offered a LMS for voluntary adoption by faculty since 1997. The current version of our system, CTools, is built on the Sakai architecture (see www.sakaiproject.org). Approximately 80% of our faculty report using CTools and 98% of our students have had at least one class using CTools. In the current term (Fall 2006), there are over 3,800 course sites and over 17,000 individuals log in to the system one or more times on an average day. All faculty, students, and staff at our university can also create their own project sites in CTools and subscribe any number of members to that site. As our LMS has become part of the basic IT infrastructure for our campus, the number of project sites has increased dramatically. Figure 1 shows the growth in project site creation for the first two months of the Fall 2005 and Fall 2006 terms. For the Fall 2006 term, students initiated 1,110 new project sites which is 64% of all project sites (n = 1,750) created between August 23 and November 16.

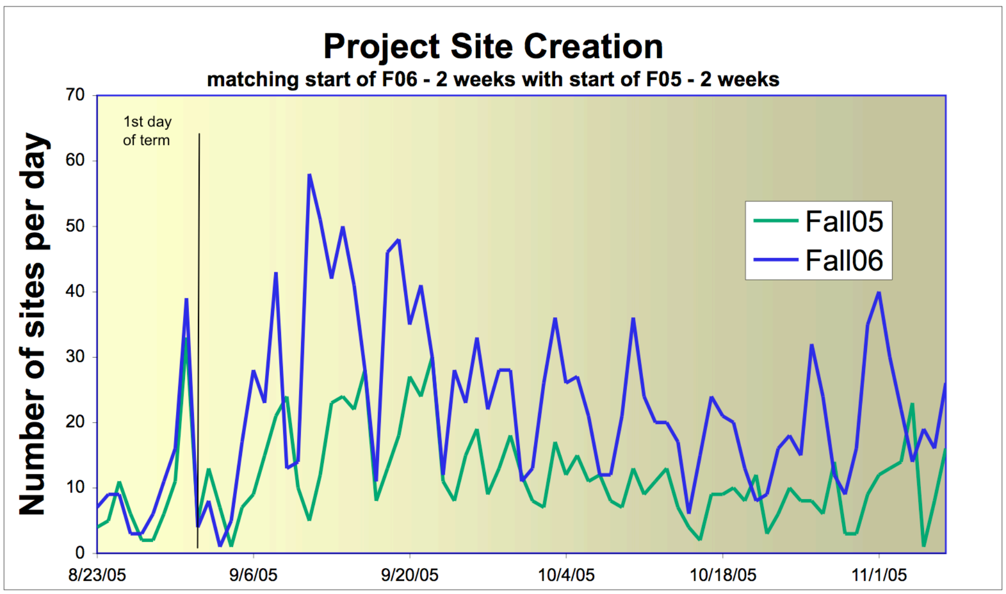

Figure 1. Fall 2005 and Fall 2006 Project Site Creation

In the CTools environment, both course sites and project sites appear as tabs across the top of the browser window, but users see only the tabs for the specific course and project sites to which they are subscribed. Faculty and student users are automatically subscribed to course sites by the registrar's office, but project sites members are added by the site creator. Project sites offer much of the same functionality as course sites; users can make announcements, post to a shared calendar, contribute and edit resources, and participate in discussion boards, chats, wikis and soon, blogs. Prior research on project sites (Teasley, Rader, Morgaine, Angell, & Narvid, 2006) has shown that sites are used primarily for posting materials to resources (98% of all sites), but users also made announcements (39% of sites), added events to the calendar (22% of sites), posted to a discussion (15% of sites) and posted to chat (15% of sites). Wikis and blogs were not yet available to users at the time of the previous analysis.

In April, 2006, we surveyed all instructional faculty at our institution and sampled from 25% of the undergraduate and graduate student population. The response rate was 19% from faculty (n = 1,360) and 27% from students (n = 2,485). Our survey asked general questions about preferences, use, and benefits of information technology in classes; as well as more specific questions about CTools features, usability, and open-ended questions on improvements for CTools. We included a number of questions from the 2005 ECAR Study of Students and Information Technology (Caruso & Kvavik, 2005). Although intended primarily to understand the course-related activity within CTools, we did ask several questions about project site use. Specifically, we asked respondents to indicate their experience with project sites and to rate the overall value for three categories of use: research, student work, and administrative tasks. Not surprisingly, we found that more faculty than students had experience using project sites for research (25% vs. 10%) and administrative work (22% vs. 9%), although both types of users rated the value of these two kinds of site use highly (83-90% of all users rated them "valuable" or "very valuable"). Experience with project sites used for student work was similar for faculty (20%) and students (23%), and was also rated equally highly by both groups. Specifically, we found that 91% of faculty and 89% of students rated this kind of use as valuable or very valuable. This suggests that both the students who use the projects sites as well as the faculty who have experience with how students are using them believe that the sites are adding value to students' educational experience. A review of the names of student-initiated project sites created in the current term illustrates some of these uses: using project sites for a course's required group projects (e.g., in a Mechanical Engineering class; "ME395Team3," "ME395sec6team4"), science lab groups (e.g., "Lab Group 2"), and group study sites (e.g., "History Honors Com," "EDUC 695 Lit Review").

Log data from Fall 2006 shows that the student-initiated project sites had an average of 4 members per site (mode), although sites ranged in size from 1-1008 members. An examination of the tools on the sites showed that 97% of the sites have resources, 82% have announcements, 60% have chat, 59% have a threaded discussion, and 32% have a wiki. These findings suggest that while most students may be using project sites to broadcast information out to a large group (e.g. resources and announcements), many students may be using the interactive capability of the sites (e.g. chat, discussion, wiki) to build collective knowledge and learn from one another.

Ongoing Research

In March 2007, we conducted a student survey of project site creators (N=306, 31% response rate). Preliminary results from this survey indicate that the majority (70%) of the project sites students used the most were created for course-related projects. The survey results also indicated that the LMS tools students value most for collaboration are Resources, Announcements, and Email Archive. The majority of survey respondents (53%) participated in one or two project sites in Fall 2006, and 52% visited those sites a few times each week. Sixty-two percent of students reported that they participated in a project site for only one term, and 17% of students participated in project sites for more than one calendar year.

Based on data from the event logs and surveys, we will select several project sites to study in depth by interviewing the student users of these sites and examining the everyday use of their project sites. By analyzing interview, survey, and log data sources in concert, we plan to capture how students use project sites to shape the nature of their self-directed collaborative learning experiences with peers.

Impact

We believe that the findings from this research will help demonstrate how CTools and other LMS can be used to support collaborative learning in higher education. As these systems become ubiquitous in higher education, it will be increasingly important to move the focus from faculty use to student use to determine how students can leverage the capacities of these systems in service of their own learning.

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Tools for Concurrent, Embedded, and Transformative Assessment of Knowledge Building Processes and Progress

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Abstract: In this paper we introduce a suite of analytic tools to enable users of Knowledge Forum to monitor various participation and collaboration patterns, with almost instantaneous feedback to ongoing processes. Tools for semantic analysis of content similarly provide just-in-time assessment (e.g., vocabulary overlap for different documents or Knowledge Forum database segments). Early results suggest a number of ways in which concurrent and embedded assessment enhances knowledge building in classrooms.

Background

Knowledge building systems, with formative assessment, can be conceptualized as a cybernetic system with feedback loops serving to drive the system in new directions (Roos & Hamilton, 2005). To optimize performance feedback must be relevant and timely. Analysis of discourse from computer-supported collaborative learning environments is common but, as Lee, Chan & van Aalst (2006) note, relatively little attention has been paid to the "formative, embedded, and transformative aspects of assessment in collaborative inquiry". In this paper we introduce a suite of tools that are embedded in Knowledge Forum® version 4.6 as a series of Java applets. Results can be made available to any user (teacher, student, manager, at the teacher/manager discretion). Designs also aim to empower users rather than engage them in competitive analysis, with much of the focus on community dynamics and knowledge advancement. With appropriate safeguards and attention to issues of security, data can be read directly from the Knowledge Forum database, and integrated back into it, thereby transforming the dynamics of knowledge building (Scardamalia, 2002).

Participation and Collaboration Tools

A previous Analytic Tool Kit for Knowledge Forum (Burtis, 1998) included participation and collaboration tools. The Contribution Tool (Figure 1) provides information about the number and nature of artifacts created by participants at the individual and group level. The tool provides measures of the number of notes created, the number of views in which participants worked, and other measures of individual and group performance, but it does not provide information about the relationships between individuals. That is the realm of the Social Network Analysis Tool (Figure 2), which displays the social relationships among participants based on patterns of behavior recorded in Knowledge Forum (e.g., who read/referenced/built on whose note).

Writing Analysis Tools

One of the advantages of CSCL environments is that they provide access to digitized records of the contributions of the participants. Thus, all utterances are recorded and are available for analysis. Various studies now indicate that advances in textual and graphical literacy are important by-products of work in knowledge building environments (Sun et al., 2006; Gan, 2006). In an effort to better identify such growth we have developed several writing analysis tools. These tools parse and quantify the contributions of participants in terms of vocabulary growth (Figure 3) and basic writing measures (e.g. total and unique words, mean sentence length).

Semantic Analysis Tools

The Participation, Collaboration and Writing Analysis tools focus on surface features of contributions. The Semantic Analysis Tools deal with the meaning of the discourse. The Semantic Overlap Tool extracts key words or phrases from a user-selected subset of the discourse and reports the extent to which that subset overlaps with another user-selected subset of the discourse. One application of this tool is to examine the overlap between a participant's discourse and discourse generated by experts in a discipline or in curriculum guidelines. Other applications include the examination of overlap between two or more participants. The Semantic Field Visualization Tool (Figure 4) provides graphical displays of the overlap of the semantic fields of subsets of the discourse by employing techniques from Latent Semantic Analysis (Deerwester et al., 1990; Landauer et al. 1998).

Transformative Assessment to Support Knowledge Building

In the past, teachers using Knowledge Forum software assessed student performance through observation of classroom interactions and reading students' notes. While detailed information was available from the Analytic Tool Kit, the tools were used by researchers, not users, and for summative evaluation rather than input to ongoing practice. The just-in-time nature of the new tools is changing that.

The teacher can use the Contribution Tool during or immediately after each session to determine how productive each student has been.(e.g, how many notes were read, created or modified). Such information helps the teacher direct attention to students who may need more support or instruction, and helps them identify barriers preventing students from participating fully in the knowledge building community.

The Social Network Analysis Tool can help teachers to better understand who the central participants are in the knowledge building discourse and to see if existing social relationships are limiting or impacting positively on the community's work. The tool draws the teacher's attention to children who are on the periphery and makes it more likely that these children will receive the direct support they may need to be more integral to the work of the class.

Looking at the growth of vocabulary relative to outside measures or benchmarks gives the teacher a good indication of whether the students are learning and using concepts in the discipline, at or above grade level. Information about the complexity and quality of children's notes can also give the teacher clear direction as to the type of guidance or instruction the class may need. All of the tools support the teacher in planning in a way that is responsive to the students' evolving needs.

The various dimensions of the analytic tools identified here, and additional aspects of their use can be seen through the work of a teacher demonstrating how these tools are used to engage all students more productively in knowledge building (http://ikit.org/video/assessment/).

Future Work

Because the use of the assessment tools is tracked in the same database in which the participant-generated discourse is stored it is possible to examine the changes in discourse patterns that result from the use of the tools. We are currently designing a series of experiments that will track the nature of changes to the discourse that occur as a result of the use of the assessment tools. For example, does knowledge about participation patterns enable teachers to engage all students? Does information about semantic overlap with discourse generated by experts support knowledge advancement?

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Acknowledgements

The authors wish to acknowledge the generous support of the Social Sciences and Humanities Research Council of Canada. We would also like to acknowledge the software engineering talents of Jud Burtis (Vocabulary Tool), Paul Johnson (Contribution and Social Network Analysis Tools), and Ben Smith Lea (Writing Tool).

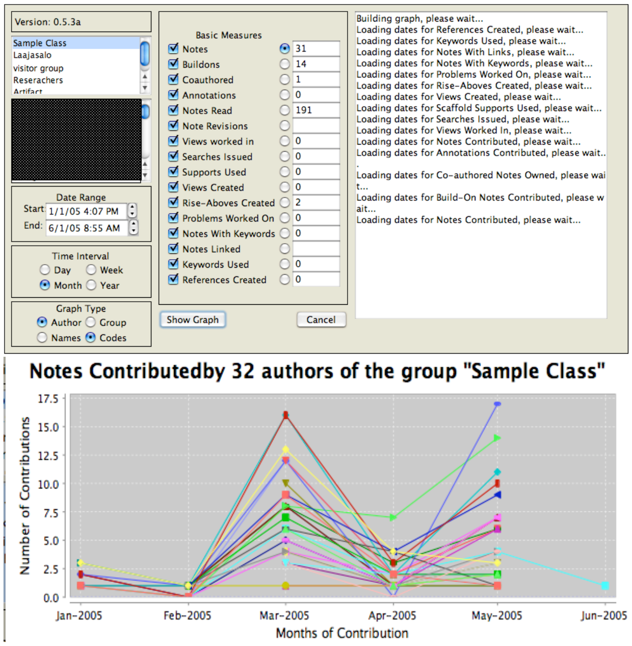

Figure 1. The Contribution Tool.

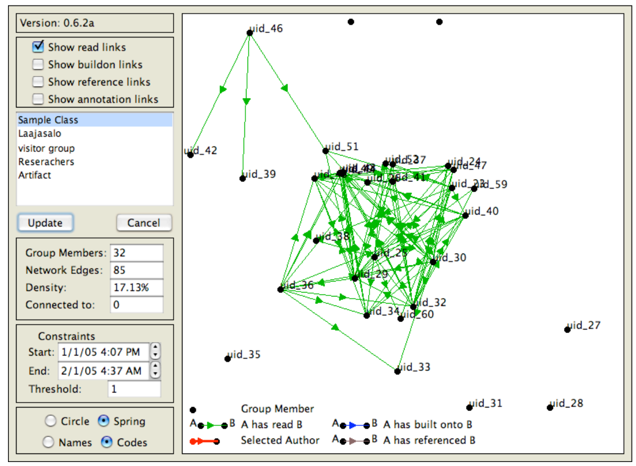

Figure 2. The Social Network Analysis Tool.

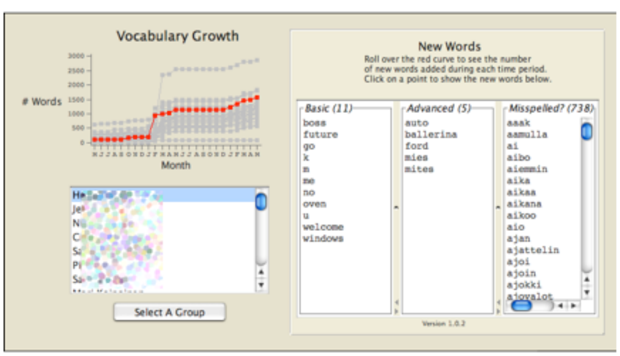

Figure 3. The Vocabulary Growth Tool.

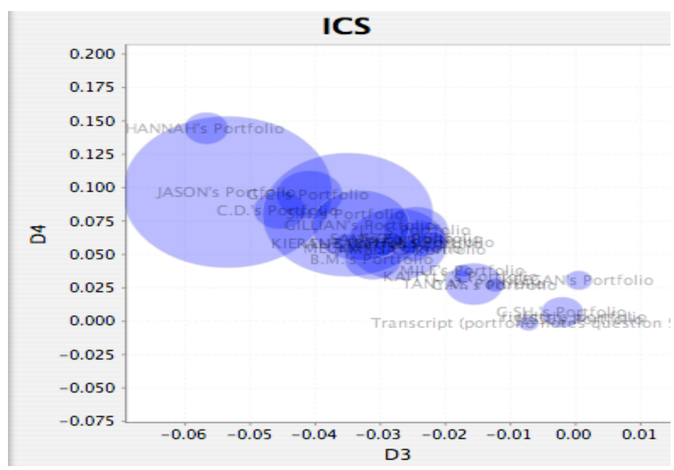

Figure 4. The Semantic Field Visualization Tool.

Boundary conditions for applying argumentative diagrams

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Abstract: In this paper, we examine two factors that may influence the use of diagrams in computer-supported collaborative argumentation-based learning: students' preference for and ability to construct and read argumentative diagrams as opposed to argumentative texts, and the complexity level of presented information. Fifty-two high school students and 74 undergraduates completed a questionnaire on preference for argumentative texts or diagrams with different levels of difficulty. The high school students were also asked to construct texts and diagrams. Results show that preference for textual or diagrammatic representation depends on the level of difficulty of the represented information. The results suggest that learning with argumentative diagrams is only perceived to be beneficial with a medium level of information complexity. Sub optimal diagram construction in our previous studies on computer-supported collaborative learning may have been due to the complexity of the information.

Introduction

Computer-supported collaborative argumentation-based learning is described as an activity in which two or more people construct knowledge by discussing a topic in a computer-environment. People learn from argumentative interaction because it involves reasoning instead of merely retrieving information from memory (Andriessen, Baker & Suthers, 2003). They have to explicitate their thoughts, need to look at information from different sides, and search for causes and relations in the topic under discussion.

The broader and deeper learners' discussions, the more they can learn. However, good discussions do not automatically occur. Most people have difficulties with argumentation, especially with looking at a topic from different perspectives, and countering viewpoints (Chan, 2001: Felton & Kuhn, 2001). One reason for these difficulties is that argumentation is not linear, and consequently, it is hard to get a good grip on the space of debate through temporal linear discussion. Argumentative diagrams can be used to support argumentation-based learning. An argumentative diagram displays arguments in boxes, and relations between these arguments in arrows. There are various advantages to diagrams. For example, a diagram can represent the structure of the argument and the relations between different viewpoints and arguments, or be the basis for further discussion. However, less is known about the boundary conditions for applying diagrams. Students seem to not always exploit the benefits of argumentative diagrams (e.g., Munneke, Van Amelsvoort & Andriessen, 2003). They are very apt at understanding how to create a diagram, but they seem not to understand its possible added value of structure and relations for guiding discussions and learning.

We wanted to know if and when students consider argumentative diagrams useful for learning. We investigated two possible boundary conditions. First, we examined students' preference for and ability to work with diagrams as opposed to text. Research into visual and verbal learning is not new (e.g., Sternberg & Zhang, 2001; Mayer & Massa, 2003). However, two problems arise in applying these studies to argumentative diagrams. Firstly, the term 'visual' is not accurate for describing argumentative diagrams, since these kinds of diagrams are very 'texty'. Argumentative diagrams are both verbal and visual. To our knowledge, there is no questionnaire available that investigates students' preference and ability for argumentative diagrams as opposed to plain argumentative text. Therefore, we constructed one ourselves. Secondly, we believe that an important factor in students' preference and ability is complexity level of the information represented. Students may not consider argumentative diagrams beneficial when the information is very complex, because this impairs structure and overview. Therefore, we also investigated students' preference and ability while varying information complexity.

Study 1

Method

Fifty-two high school students (23 boys and 29 girls) participated in the study. They were asked to complete a questionnaire before engaging in a discussion task with chat and diagram. The questionnaire consisted of two parts. The first part asked about preference for either texts or diagrams and consisted of seven questions. The first question asked for students' general preference for information presented in text or diagram. In the other six questions, information was presented in both text and diagram (see Figure 1), with three different levels of information complexity. Students were asked to choose the representation they preferred, and to indicate level of difficulty of understanding the two representations on a 5-point Likertscale. The second part about ability consisted of three assignments in which students were asked to construct a diagram from text or write a text from a diagram.

I think she is suited for this job. She had the required education, has over five years of relevant work experience and has excellent communication skills. However, recruiting her is very expensive because she has been working for a long time.

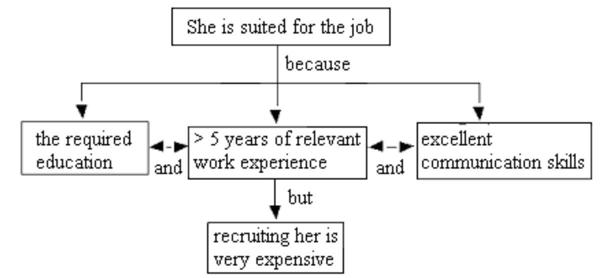

Figure 1. Example of a question (textual and diagrammatic representation).

Results

Reliability of the questionnaire was good, Crohnbach's alpha ranging from .72 to .82 when distinguishing between the questions on preference and complexity level. The interrater-reliability for the ability part of the questionnaire was .77 (Cohen's kappa).

On the first question, 64.7% of the students indicated a general preference for verbal information, and 35.3% for diagrammatic information. A score on general preference for verbal information correlated highly with perceiving the textual information as easier than the diagrammatic information. However, when the complexity level was low or high, students tended to prefer textual information, while when the complexity level was medium, they preferred diagrammatic information.

Students' ability to construct texts from diagrams and diagrams from texts also related to the information complexity. At the lowest level of information complexity, 51 out of 52 students scored the highest possible score. At the highest level of information complexity, 4% scored low, 71% scored medium, and 21% scored high. There was no correlation between preference and ability, nor between students' score on the questionnaire and their performance on the collaborative argumentation-based learning task.

Study 2

Method

Seventy-four undergraduate psychology students were asked to complete the first part of the questionnaire to investigate the question 'Do preferences for textual or diagrammatic information change with complexity level?' further. Part one was extended with two questions, to create four different complexity levels (easy – medium – complex – very complex).

Results

When asked what representation students preferred in general, 72.6% chose verbal information, and 27.4% chose graphical information. On the five-point Likertscales students indicated that textual information (M = 1.86, SD = .64) was easier than diagrammatic information (M = 2.56, SD = .84). Level of perceived difficulty of understanding ranged from 1.16 to 2.27 for the textual information, and 2.24 to 3.73 for the diagrammatic information.

Preference for textual or diagrammatic information was dependent on complexity level: while only 20.9% of the students preferred diagrammatic over textual information when information was at the extreme ends of complexity-level (easy or very complex), 55.5% preferred diagrammatic over textual information when it was medium or complex. Students who indicated a general preference for *verbal* information preferred the textual representation at the first and last two levels of difficulty, but the diagrammatic representation at the medium level of difficulty. They always considered the textual representations to be easier than the diagrammatic representations.

Students who indicated a general preference for *graphical* information preferred the diagrammatic representation at the medium and difficult level, but the textual representation at the extreme ends of difficulty-level. In addition, they indicated diagrammatic information as easier than textual information only at the two middle levels of difficulty. In short, we found a curvilinear relation between preference for verbal or visual information and complexity of the represented information (see Figure 2)

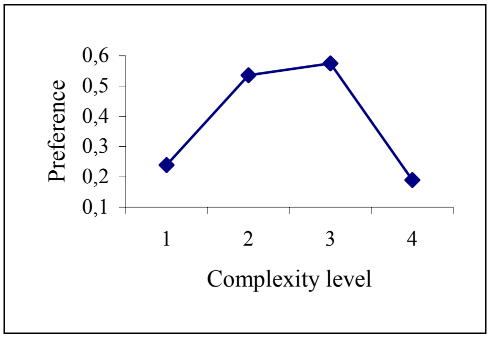

Figure 2. Preference for text (0) or diagram (1) related to complexity of information

Discussion

Reading and constructing argumentative diagrams is not easy. Although an argumentative diagram can be beneficial for collaborative argumentation-based learning, there are factors that can influence its beneficial effect. In this paper, we investigated students' preference for and ability to read and construct argumentative diagrams with different complexity levels. In general, most students prefer textual over graphic information. However, the complexity of information that is represented influences students' preferences. Argumentative diagrams are preferred over text when the represented information is of medium complexity. We also found that students' have more difficulty constructing diagrams from text when the information is complex. Our results imply that argumentative diagrams may only be useful for learning when the information (to be) represented is not too easy nor too complex. A very simple diagram does not have added value over text, because there is no need to see structure or relations. When a diagram is very complex, the benefits of showing structure and giving overview are not present anymore. Our studies investigated students' individual ideas on mostly presented diagrams. Further research is now needed to investigate whether this assertion stands when students construct diagrams in collaboration.

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Small-group Face-to-Face Discussions in the Classroom: A New Direction of CSCL Research

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Abstract: This paper presents a relatively new direction of CSCL research: small-group learning *in* the classroom. This research direction has received relatively little attention within the CSCL community. In this paper we explore the possibilities of collaborative technology in the classroom. We use the distinction between task-related and social-emotional interactions as a criterion for computer support. It is hypothesized that the students will use the collaborative technology purely for task-related interactions when the characteristics of the tool closely match the conditions for an effective task performance. It is assumed that these task-related interactions stimulate knowledge elaboration and learning within the student group. Our findings indicate that all computer-mediated interactions were task-related and facilitated knowledge elaboration. Oral communication was about the social-emotional aspects of the collaboration, and the planning and regulation of the collaborative activities.

Introduction

Small-group learning refers to the *intelligent* social practice of a group of students who work together on a common task. The denomination 'intelligent' emphasizes that the group has the ability to alter their learning activities in response to past experiences, new information or divergent perspectives. This ability cannot be traced back solely to individual cognition but rather emerges from students' interactions. It is assumed that, *under the right conditions*, students may benefit from their collaboration and will outperform students who learn alone. Small-group learning as an instructional method demands a lot from the students. Students have to work together on a common task, often without close guidance from the teacher. They have to deal with various problems, cognitive as well as social in nature. It is assumed that use of computers may help the students to overcome some of these problems. Computers could facilitate collaboration and learning within the group and it may support the students to achieve their learning goals.

A wide variety of computer applications has been developed to support small-group learning. These tools stimulate specific cognitions and behaviors that are expected to be beneficial for learning. We distinguish three small-group learning situations for computer support (Figure 1). Our categorization is based on one type of collaborative learning practice: problem-solving discussions. It underlines that small-group learning is generally organized around a problem-solving task and that it takes its shape as a *problem-solving discussion*.

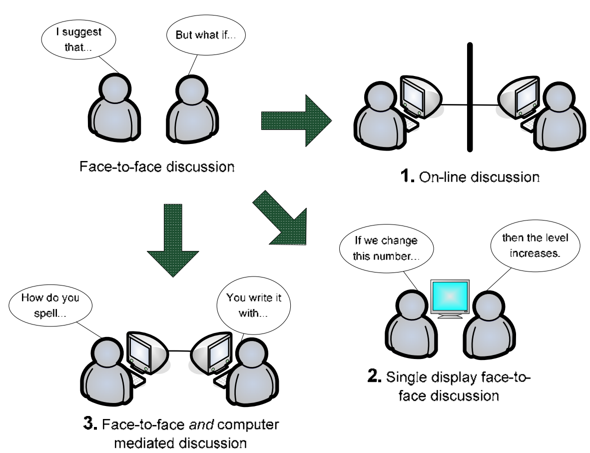

Figure 1. Three situations of computer support for small-group learning

The first situation (upper right corner of Figure 1) refers to the use of computers to connect students who are dispersed in time and/or space. The majority of CSCL research focuses on this type of situation where *all* the interactions are mediated by the technology. For many researchers, this represents the archetypal CSCL research context. The other two situations of figure 1 have a fundamentally different orientation. They consider the existing classroom context as taken for granted. These situations have two distinctive features: 1) students are in the same room in close proximity and 2) they communicate face-to-face. The *second situation* (lower right corner of Figure 1) represents a situation where students are co-located and work with a stand-alone computer application. These applications typically model a problem situation that the students have to investigate. Such computer models display processes that change with respect to time. Students can manipulate the model and get feedback about their intervention by running a simulation. This form of CSCL – sometimes referred to as '*single-display groupware*' – has received some investment in terms of research. The *third situation* represents a learning environment where students communicate face-to-face *and* simultaneously use a collaborative technology. It means that one part of their communication will be face-to-face, while the other part will be computer-mediated. This situation is the object of our study.

The combination of face-to-face and computer-mediated communication is largely ignored by the CSCL community. CSCL research mainly focuses on situations like distance collaboration, online learning and virtual teaching where the support is primary considered as a means to bridge time and space between the students. Overcoming time and space limitations has a direct added value, but it also leads to a specific focus. It considers group interaction, in its broadest sense, as the main determinant for collaboration and learning. However, research into distance learning indicates that it is extremely difficult to facilitate the full range of group interactions by collaborative technologies. Computer-mediated interactions are often restricted to those interactions that mirror the cognitive processes in a group (Kreijns, Kirschner and Jochems, 2003). An enrichment of the information flow may improve online collaborative learning: for example, students may use multiple tools simultaneously to enrich their communication, or they may use an awareness tool that provides them with detailed information about their performance. The aim of these interventions is to broaden the range of cognitions and behaviors that are necessary for collaborative learning. They seem to reflect 'a return' to the richness of face-to-face communication. Still, it remains unclear if online collaboration can *and* should mirror its face-to-face counterpart. Research into computer supported collaborative work (CSCW) seems to indicate otherwise (Olson & Olson, 2000; Kiesler & Cummings, 2002).

We will argue that the partial orientation on online collaborative learning may limit our understanding of the potentials of computer support. We would like to stress that most learning still takes place in classrooms where the students are located near each other and collaborate face-to-face. Ignoring these face-to-face classroom situations would deprive the CSCL community of a promising direction for research and development. We will present an exploratory study to indicate that collaborative technologies may also be beneficial in situations where the students are co-allocated (1).

Problem-solving discussions in the classroom

Small-group learning has traditionally been studied in classroom settings where students meet face-to-face to solve problems. (for an overview, see e.g., Cohen, 1994; Webb & Palincsar, 1996; Slavin, Hurley & Chamberlain, 2003). Small-group learning is often conceptualized as a *problem-solving discussion* between a group of students. Problem-solving discussions generally consist of several interrelated phases that are directed towards the resolution of a particular problem. Problem-solving discussions can be dynamic, difficult to grasp and hard to manage. Students who solve a problem collaboratively have to manage different kinds of processes. On a general level, two processes can be identified: students have to *solve the problem* and they must *maintain a satisfying level of collaboration*. These two processes are associated with two distinct types of interactions, i.e. task-related and social-emotional interactions (Bales, 1950).

Solving the problem: task-related interactions

The first requirement – solving the problems –requires a lot from the cognitive abilities of the students, especially in the case of ill-structured or ill-defined problems. These types of problems don't fulfill the rational, goal-directed strategies that are associated with cognitive analysis of human problem solving. They refer to situations where it isn't clear at the beginning what the problem exactly is *and* which actions may lead to the solution of the problem. The cognitive processes that underlie the problem-solving activities of the group are difficult to model and open to different interpretations. Solving these problems requires the application of multiple perspectives and mutual knowledge. Different perspectives and mutual knowledge create opportunities for higher-order thinking (Schwartz, 1995). The group processes that relate to 'solving the problem' emerge from the *task-related interactions* within the group. They are used to explicate the task processes in groups. It enables group members to share and use knowledge and information that are directly related to task performance (Propp, 1999).

Group well-being: social-emotional interactions

A second complicated factor has to do with maintaining a satisfying level of collaboration. When students collaborate they have to maintain durable relationships and acceptable levels of participation. Interactions that are associated with these aspects of the group performance can be typified as *social-emotional interactions*. These interactions are primarily directed towards the relationship between group members. They affect student's perception of the other group members and the relationships they form (Propp, 1999). The minimal number of categories of social-emotional interactions would include control and affection (Hare, 1960).

Facilitating collaborative learning

A shift from online towards face-to-face collaborative learning brings along a shift in the kind of interactions that should be mediated by the computer. Online collaborative learning seems to reflect an attitude of *'more support is better'*, i.e. a richer information flow between the students is seen as a guarantee for collaboration and learning. In contrast, the starting point for face-to-face collaborative learning is fundamentally different: students can already communicate *without* the support of computers. This observation draws the attention to those interactions that can be facilitated by the collaborative technology *and* that would improve learning. It seems that "*less but specific support*" is the leading principle. When the students work with the collaborative tool, their interactions will be distributed between the two modes of communication, i.e. an oral, face-to-face and an electronic, computer mediated part. At least two questions have to be addressed when collaborative technologies are introduced this setting:

- What are the characteristics of an effective face-to-face problem-solving discussion in the classroom?
- How can a collaborative technology, that mediates part of the communication between the students, improve a face-to-face discussion?

Effective face-to-face discussions

We will use the distinction between task-related and social-emotional interactions as a criterion for qualifying group discussions and to identify requirements for computer support. It is assumed that the students may benefit from a clear distinction between task-related and social-emotional interactions. Task-related interactions are associated with learning. It leads to cognitive activities often referred to as knowledge elaborations, which, in turn, are responsible for knowledge acquisition (Draskovic, Holdrinet, Bulte, Bolhuis & Leeuwe, 2004). This would imply that the students should be encouraged to perform their task-related interactions within the shared workspace of the collaborative tool. It is hypothesized that this could be achieved by a design that closely matches the characteristics of effective task performance. Students will use the tool purely for task-related communication when the characteristics of the tool facilitate the problem solving.

Computer mediated interactions

One type of task-related interaction that has been associated with learning is "asking questions". The aim of asking a question is to elicit a verbal response from those to whom the question is addressed (Keatsley, 1976). Students may be encouraged to elaborate on existing knowledge when they ask questions. Knowledge elaboration, on its turn, facilitates the acquisition of that knowledge (King, 1994). It is hypothesized that both 'asking questions' and 'making comments' would stimulate a constructive problem-solving discussion between the students. Asking question and giving comments may encourage the students to elaborate further on a topic by exhibiting behaviors like giving examples to explain an idea; providing evidence for a statement or giving reasons as grounds for a conclusion. Both communicative acts have the function to elicit a response. A question is more explicit in triggering a response. Making a comment expresses of a reaction that, on it turn, may trigger a response from the 'listener'.

To summarize, we identify to following principles and hypotheses with regard to computer supported collaborative learning in the classroom:

- The task-related interactions will lead to knowledge elaborations.
- Students will use the collaborative tool for task-related interactions when this tool is designed in such a way that it closely matches the conditions for effective task performance.

- A collaborative tool that stimulates task-related interactions like 'asking questions' and 'making comments' would stimulate a constructive problem-solving discussion.

These principles and hypotheses are "translated" into the collaborative tool as design principles. These design principles will be evaluated in practice. The evaluation of these principles implies a test of the principles and hypotheses that underlie the design. It means that we can draw conclusions about these principles and hypothesis through the evaluation of the design. The design activities, in our study, are a natural continuation of the theory development activities. The principles and hypothesis that we discussed are made applicable for evaluation through the design.

Design research

Our research approach is in accordance with the "design research" approach. Design research combines theory-driven design with empirical educational research. The approach entails both 'engineering' particular forms of learning *and* systematically studying those forms of learning within the context defined by the means of supporting them (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003). It explicitly exploits the design process as an opportunity to advance researchers' understanding of learning processes (Edelson, 2002).

For our research we used a graphical shared-workspace tool: the Digalo. We expected that the Digalo would stimulate task-related interactions that will lead to knowledge elaboration. We used the two communicative acts – i.e. asking questions and making comments – as a starting point for our design. They were implemented in the notation system of the Digalo.

Digalo: The graphical shared-workspace tool

The Digalo tool provides its users with a shared workspace based on a concept-mapping interface (Figure 2). Users can put forward contributions simultaneously into a shared workspace by using a predefined notation system. They can also relate associated contributions by drawing a link between these contributions.

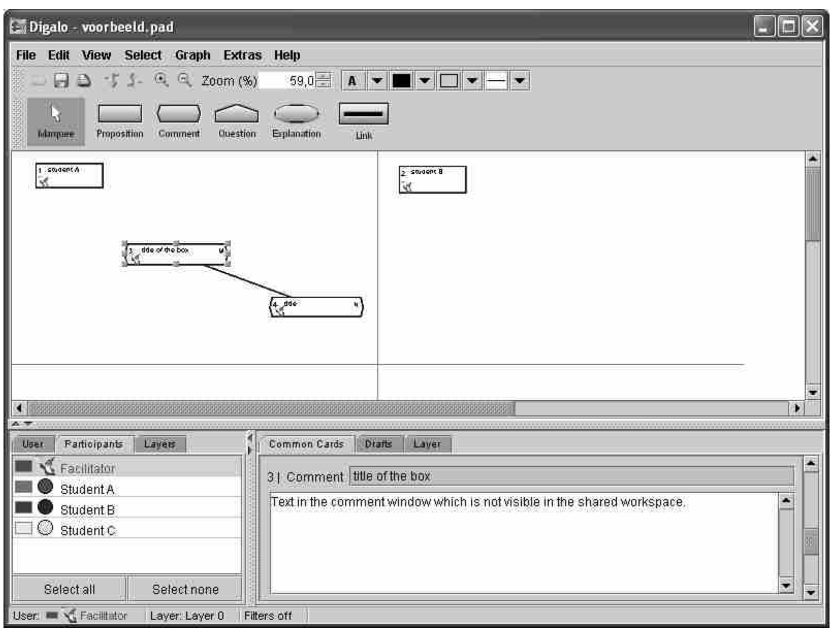

Figure 2. User interface of the Digalo tool

A notation system consists of a set of labels or contribution cards that represents certain communicative acts. The notation system that the students used in our study consists of three labels: 1) proposal, 2) question, and 3) comment. A student has to select a label before she types in a text and places that text in the shared workspace. Different types of contributions could be identified in the shared workspace by their shape. The student may want to type in more text than the shape could contain. In that case could the student can type in additional text in the comment window. The additional text becomes visible when a student selects a contribution – i.e. shape – in the shared workspace.

Methodology

The research that we discuss in this paper has been carried out at a secondary school with a class of 5th grade students of a Dutch language course. The class consists of 19 students, divided over groups of two or three members. The seven groups had to write a paper for the school's board of directors. The paper should contain an advice about how to promote a respectful discourse in the classroom. The policy note was a group product. The pedagogical objectives associated with the assignment were:

- developing discussion skills with an emphasis on analytical and argumentative skills,
- developing collaborative skills,
- developing writing skills.

Our study discusses the third lesson of a sequence of 6 lessons where the students worked on the assignments. The third lesson consisted of two activities: 1) each student had to formulate a proposal about how the school should improve a respectful discourse and 2) the students should discuss the proposals with their group members. Each group of students formulated and discussed their proposal with the support of the Digalo. The students sat near each other so that they could communicate face-to-face.

Micro analysis of the Digalo mediated actions

We have two sources of data for analysis: 1) audio recordings of verbal interaction during the discussion, and 2) the Digalo mediated actions of the students that were recorded by the tool. Our analysis of the Digalo mediated actions were divided into two parts. First, we identified the sequences of related communicative acts. We used graphical characteristics of the diagram to identify the interaction sequences. Second, we coded the individual communicative acts of the students. We develop a coding schema that focused on the task-related interactions.

Interaction sequences

We focus our analysis on the interaction sequence that consists of related communicative actions from several students. A sequence consists of minimal three related actions. Weick (1979) defines such a sequence as a double interact. An action by actor A evokes a specific response in actor B, which is then responded to by actor A (Weick, 1979). The minimal amount of actions to make up a sequence consists of *at least three related* contributions from at least two different students. The diagrams that represent the problem solving discussion of the students are used to (re)organize the contributions for coding. To identify the interaction sequences we used two of the three organizing principles – link and spatial grouping – that the students used to organize their diagrams (van Diggelen, Overdijk & Andriessen, 2004). The linking principle refers to the possibility to draw a link between related contributions. The spatial grouping principle underlines that contributions that are displayed in close proximity from each other, are related.

Individual communicative acts

We identified six different categories of actions that can be associated with the in-depth elaboration of knowledge (Hargie & Dickson, 2004; King, 1994; Pena-Shaff & Nicholls, 2004). The six categories were associated with the two types of contributions within the Digalo environment – question and comment – that stimulate elaboration (see Table 1):

- Specify,
- Inference,
- Judgment and evaluation,
- Application,
- Comparison and contrast,
- Conflict.

A final category consists of non-task communication. Each sentence that was put forward in Digalo – *and* is part of an interaction sequence – was coded by two coders (interrater reliability 0.9). We choose the sentence as basic unit of analysis because a contribution generally consisted of several sentences and students sometimes addressed several topics in one contribution. The contributions that were linked with other contributions were organized into a sequence of related contributions. These sequences were presented to the raters. Each contribution was then analyzed on the level of sentences.

Table 1: Coding scheme

Communicate act		**Code**	**Description**
Question *Evoke a response to provide unknown information or to rethink a previous action or response*	Specify	Qspe	Encourage respondents to examine an idea in more detail by drawing attention to a neglected aspect of the idea.
	Inference	Qinf	Encourage respondents to give evidence, arguments or reasons (causes and consequences) or to reach a conclusion based on evidence, arguments or reasons.
	Judgment and evaluation	Qjud	Encourage respondents to give an opinion, make value-judgments or judge the relevance of solutions.
	Application	Qapp	Encourage respondents to provide examples, i.e. concrete or specific instances of an idea or thought
	Comparison and contrast	Qcom	Encourage respondents to consider similarities and differences between situations.
	Conflict	Qconfl	Encourage respondents to consider alternative or opposite point of views or positions.
Comment *Express an opinion or a response*	Specify	Cspe	Provide a more detailed analysis or a clarification of ideas and thoughts
	Inference	Cinf	Provide evidence, arguments or reasons, reach conclusions or make predictions
	Judgment and evaluation	Cjud	Express an opinion, make value-judgments or judge the relevance of solutions, listing advantages and disadvantages
	Application	Capp	Using examples, i.e. concrete and specific instances of an idea or thought
	Comparison and contrast	Ccom	Compare two situations to present similarities and differences, identify assumptions
	Conflict	Cconfl	Defending one's point of view or position by argumentation or further elaboration
Others		O	non-task communication

Results

The aim of our analysis it to explore how the interactions between the students split up in an oral and a computer- mediated part. With regard to the computer-mediated part we also want to explore how the characteristics of the tool affect the interactions within the tool. Two characteristics will be highlighted: the notation system and the ability to relate associated contributions into a sequence of communicative acts.

The interplay between face-to-face and computer mediated interactions

The Digalo tool in combination with face-to-face interaction led to a typical kind of problem-solving discussion. All the task-related interactions were mediated by the tool. All utterances expressed in the Digalo concerned the topical content of the discussion. This in contrast to research findings with regard to research of online collaborative learning, where a considerable amount of the messages is of a social-emotional or meta-cognitive nature (e.g. Pena-Shaff and Nicholls, 2004; Hara, Bonk and Angeli, 2000). This difference in findings may be due to the fact that in our research the students were co-located and could also communicate orally.

Analysis of the recorded face-to-face discussions reveals that this mode of communication was used infrequently. Students could be silent for 2 to 3 minutes. When they did communicate orally, their utterances referred to:

- socio-emotional aspects of the collaboration, e.g. asking for help, tension release by telling a joke, giving positive feedback, keeping group members focused on the task;
- planning of the activities, e.g. discussing the assignment;
- regulative aspects of the collaboration, e.g. discussing rules for computer-mediated interactions.

We may conclude that the face-to-face communication involved more than only social-emotional expressions. It also contained procedural messages that encompass the establishment and maintenance of procedures and rules for arriving at a solution and goal-related expressions that pertain to establishment and monitoring of group goals and values (see e.g. Poole and Hirokawa, 1996).

Notation system

Figure 3 gives the percentages of utterances for each category of the coding scheme (see table 1) that represent different aspects of 'in-depth elaboration' of knowledge. The students mainly asked "specifying questions" (18% of all statements) that encourage respondents to examine an idea in more detail. The comments that the students made are more diverse: students gave a more detailed account of their ideas (18 % Cspe), they gave reasons, evidence or arguments on which they base their ideas or thoughts (22% Cinf) or they expressed an opinion or made value judgments (22% Cjud). The 'comment' label was used more frequently than 'question' label during the students' interaction in the Digalo, despite the fact that a question is more explicit in triggering a response from a group member.

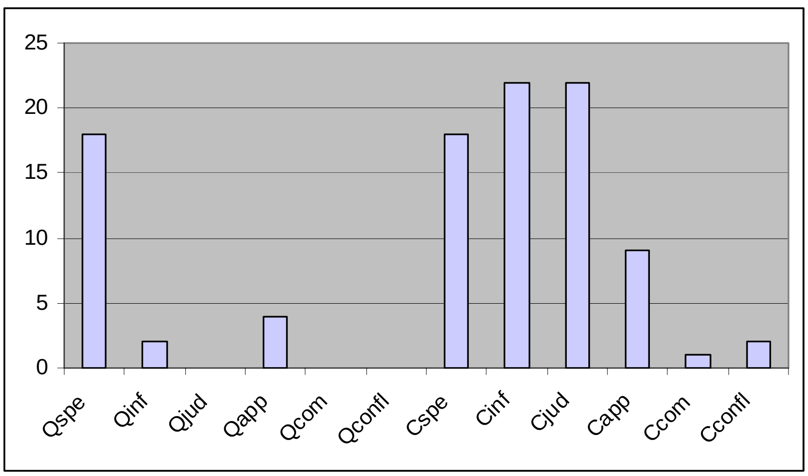

Figure 3. Percentage of 'in-depth elaboration' of knowledge indicators

One can conclude that the Digalo environment was mainly used to remove uncertainty, caused by ignorance or imprecision of a shared interpretation of the situation. The majority of the students' task-related interactions were directed towards acquiring new information that helps the group to form an interpretation of the situation. There were hardly any communicative acts that would reveal a conflict in interpretation. An analysis of the interaction sequences of the 7 groups revealed three episodes of conflict. Conflict *can* be made visible in the Digalo environment, although – in this case – it never leads to a process of negotiation within *or* outside the tool.

Interaction sequence

Our analysis of the Digalo diagrams indicates that the 7 groups produced 37 sequences. Table 2 displays the length of the sequences, i.e. the number of related contributions that make up a sequence. The length of a sequence is an indication of how extensively the students elaborated on an idea.

Table 2: The length of the sequences

	No. of contributions within a sequence								
		3	4	5	6	7	8	9	10
No. of sequences		14	9	7	2	0	2	0	3

The interaction sequences in the Digalo emerged in a parallel order. They can be considered as "discussions in a discussion". We named these sequences discussion lines. Figure 4 gives a graphical representation of group 4 that constructed six discussion lines in parallel (2.1, 2.2., 2.3, 2.4, 2.5, 2.6). The number of – parallel – discussion lines for the seven groups varied between two and six. Groups of two students produced less discussion lines than groups of three students.

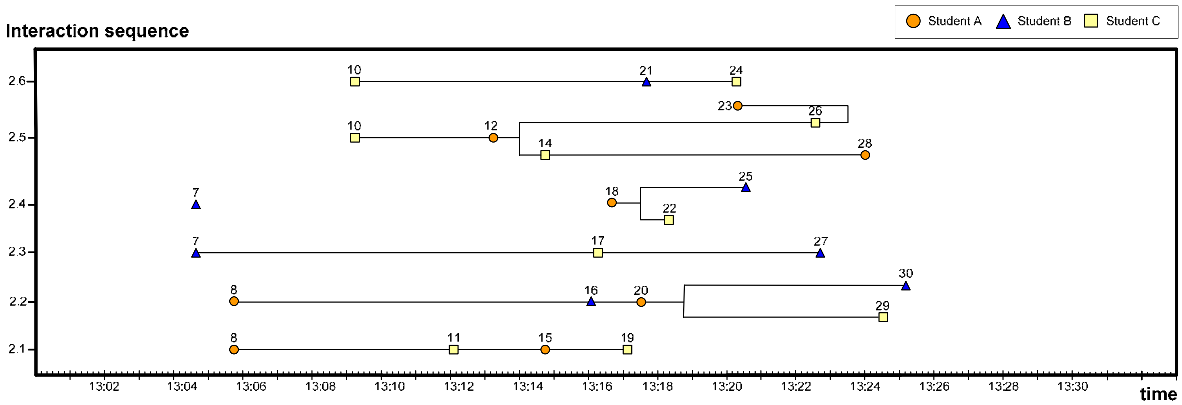

Figure 4. Interaction sequences of group 2

A graphical analysis of the students' behaviour in the shared workspace revealed that the students constantly switched between discussions lines (see Figure 5). The students "jump" from one discussion line to another; adding a contribution to a discussion line and then moving on to the next discussion line. In contrast to oral, face-to-face discussions, students seemed less constrained to one dominant course of action when they discussed a topic in the Digalo environment.

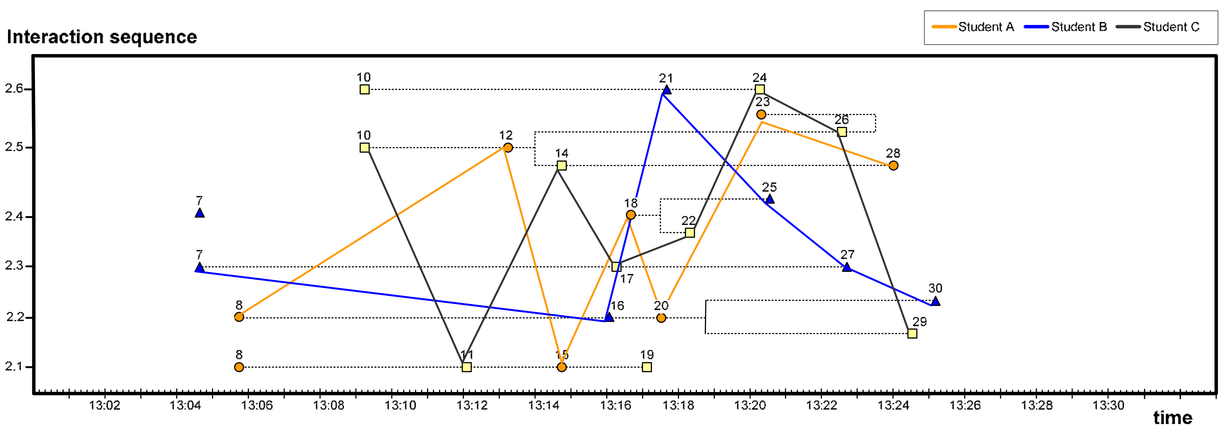

Figure 5. A spatial analysis of group 2 - jumping between discussion lines

Discussion

Computer supported collaborative learning *in* the classroom have received relatively little attention within the CSCL community. Still, it seems to be a distinct situation for research that can be set apart from the other collaborative learning situations. For example, the interactions patterns that we observed in our study differed fundamentally from the ones that are generally observed during online collaboration – e.g. a clear division of task-related and socio-emotional interactions – and during the purely face-to-face collaboration, e.g. the occurrence of parallel discussion lines. These differences seem inherent for the specific learning situation that was the focus of our study. The use of collaborative technologies for face-to-face collaborative learning seems to be a promising new direction for CSCL research. The different forms of communication may trigger different learning mechanisms and outcomes. Furthermore, a combination of computer-mediated and face-to-face communication create opportunities to optimize both means of interaction in order to maximize collaboration and learning.

The combination of both face-to-face and computer mediated communication raises new research questions that can only be addressed to its full detail in that specific research setting. A more fundamental issue would, for example, be the question: 'what are the key characteristics of face-to-face learning situation?' Olson and Olson (2000) identify several characteristics of face-to-face interactions in a situation of close proximity like rapid feedback, multiple channels, personal information, nuanced information, shared local context, informal 'hall' time before and after, co-reference, individual control, implicit cues and spatiality of reference. Still, it remains unclear if, when and how these characteristics influence collaboration and learning. Answering this question may lead to new insights that have important implications for both: online and face-to-face collaborative learning.

The use of collaborative technology may also change our perception of the 'traditional' face-to-face discussions I the classroom. Some characteristics of these discussions may change fundamentally. A good example may be the floor control mechanism. Verbal interactions in a traditional discussion are based on turn taking where participants interact by taking turns. Our observations of the interactions in the Digalo tool indicates that some of the 'limitations' of turn taking may be may neutralized by the tool. A shared workspace that is based on simultaneous access and the possibility to link related contributions enables the students to organize their discussion in a logical order that reflects their reasoning, instead of organizing their discussion in a temporal order and where meaning is based on adjacency of contributions like in a verbal discussion or a chat tool.

Endnotes

(1) This study is part of a larger research project – the LEAD project – that aims to develop and study collaborative technology for face-to-face problem-solving discussions in the classroom. The LEAD project is partially funded within the Sixth Framework Program of the EC. Information about the LEAD project can be found on: http://www.lead2learning.org.

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The Use of "Knowledge Types" as Scripting Tool to Enhance Critical Thinking in Online Discussions

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Abstract: The present study focuses on a particular scripting tool, namely the use of "knowledge types" as a way to structure university students' discourse in asynchronous discussion groups and consequently promote their learning. More specifically, the aim of the study is to determine how requiring students to label their contributions by means of the stages of the progressive inquiry model affects the ongoing critical thinking processes reflected in the discussion.
Preliminary results indicate that using this scripting tool can –under certain circumstances- enhance critical thinking in online discussions.

Objective

The present study focuses on the use of scripts to scaffold students' online discourse and to facilitate their critical thinking. The concept "script", however, encompasses a broad range of methods, techniques, and approaches. In this respect it is difficult to speak about the overall efficacy of CSCL scripts (Dillenbourg, 2002). In the present study, we are interested in the impact of a particular kind of scripting - the use of *knowledge types* - on the knowledge construction processes reflected in asynchronous discussions. As part of the course "Instructional Sciences", 287 first-year university students were engaged in asynchronous discussion groups. Two research conditions were distinguished. In the experimental condition, students were required to tag their contributions by means of knowledge types. In the control condition students were engaged in an identical assignment. However, no requirements were made with regard to labeling the knowledge type reflected in one's contributions. In both research conditions cross-ages peer tutors were following the discussion.
The study is guided by the following research questions: 1) Do students, who were required to tag their discussion contributions by means of knowledge types, differ from students engaged in regular asynchronous discussions with regard to (a) the overall depth of critical thinking, (b) the depth of critical thinking for different categories and indicators, and (c) the depth of critical thinking at successive critical thinking stages distinguished by Garrison.
2) What is the impact of differential tutor behavior?

Theoretical Framework

Critical Thinking

The present study focuses on the possible impact of collaborative learning on critical thinking, which is often cited as aim or outcome of education (Perkins & Murphy, 2006). The evolution towards an information age has focused attention on good thinking as an important element of life success. These changing conditions require new outcomes, such as critical thinking, to be included as a focus of education. Old standards of being able to score well on a standardized test of basic skills, cannot be the only means by which the academic success or failure of our students can be judged (Huitt, 1992). Oliver (2001) argues that critical thinking skills represent an important issue for education and that these skills are particularly important nowadays in order to make meaningful use of electronic information. In this respect, collaborative learning is desirable but only when grounded in disciplined critical thinking.

But although most educators agree on the importance of critical thinking for learning, there is no real agreement yet on the exact meaning of the term 'critical thinking'. For this research we go along with the definitions of Chance (1986) and Scriven and Paul (1992) who respectively define critical thinking as the ability to analyze facts, generate and organize ideas, defend opinions, make comparisons, draw inferences, evaluate arguments, and solve problems (Chance, 1986) and as the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action (Scriven & Paul, 1992).

A number of theorists have considered critical thinking as a problem-solving process (e.g., Brookfield, 1987; Garrison, 1992). Garrison (1992) more particularly identifies five phases of critical thinking. According to his theory, critical thinkers move through the stages of identifying a problem, defining it more clearly, exploring the problem and possible solutions, evaluating their applicability, and integrating this understanding with existing knowledge. The model employed to analyze the discourse in the present study is based on Garrison's model which is a dynamic cognitive one, similar to models of problem-solving used in cognitive psychology and artificial intelligence. Although Garrison initially developed it as a means of studying individual learning, it requires shared understanding with others and is therefore suitable for studying group learning as well.

Scripting

A central topic of CSCL research is how online discussion and critical thinking in particular can be facilitated. One possible approach is to realize 'computer-supported collaboration scripts'. Collaboration scripts essentially concern activities that promote learning, but which rarely occur spontaneously within the discourse of learners (O'Donnell, 1999). Scripts can be implemented as a kind of guideline. More specifically, a script can be defined as a detailed and more explicit didactic contract between the teacher and the group of students regarding their mode of collaboration (Dillenbourg, 2002). This approach is particularly interesting to specify, sequence and eventually to allocate different learning activities to learners (Weinberger, Ertl, Fischer, & Mandl, 2005).

In this study we investigate a computer-supported collaboration script, which provides a controlled list of message types from which the student must select before replying or creating a message. In the experimental condition, students were required to tag their messages by means of knowledge types, based on the FLE3 knowledge building environment. This environment is designed to support the collaborative process of progressive inquiry learning. The basic idea is that students gain deeper understanding by engaging in a research-like process where they generate problems, formulate hypotheses, and search out explanatory scientific information collaboratively with other students (Chen, 2004). More specifically, in the discussions students were asked to label each contribution with a category reflecting one of the stages of the progressive inquiry model. The provided categories were "Problem", "My Explanation", "Scientific Explanation", "Evaluation of the Process", and "Summary". In this respect, students are asked to step back and to reflect upon the ongoing discussion and on how to contribute to optimize the debate. Moreover, the labels visualize the possible predominance or absence of one or more knowledge types. This can help students to create an overview of the knowledge-building activity as it unfolds and to improve their collaboration and ability to solve open-ended problems.

Method

Participants and Procedure

All students enrolled for the course "Instructional Sciences" participated in the present study (N=286). Students were divided into discussion groups of about 8 students, with students randomly assigned to one of the 35 groups and groups randomly assigned to the research conditions. The discussion assignment was the same for all discussion groups in the study, regardless of the research condition the groups were in. Students in the experimental condition were required to tag their contributions by means of knowledge types. The online discussion environment offered a checklist interpreting the different contribution types advancing the discussion process. For each label, students received a description of what a particular knowledge type implies in terms of a discussion contribution. Taken into account that transcripts of 35 discussion groups for 4 themes represent a massive amount of data, 9 groups (*N*=71) were randomly selected for analysis.

The asynchronous discussions were a formal part of the course. Students participated during a complete semester. Four successive discussion themes of two weeks each were dealt with. During the first face-to-face session of the course, the CSCL environment was demonstrated and the objectives of participating in the discussion were communicated to the students: active processing of the theoretical base introduced during weekly face-to-face working sessions and application of this knowledge while solving authentic cases. Additional information regarding the expected participation and the criteria for qualitative messages was made available on the course website.

Fourth-year students operated as online tutors to support freshmen in their discussions. A preliminary peer tutor training was organized in a three hour face-to-face session before the onset of the discussion groups. Tutors were introduced to the multidimensional nature of tutoring in order to master a relevant mix of tutoring skills.

Content Analysis

Content analysis was applied in order to study the critical thinking processes reflected in the discussions. More particularly, a content analysis scheme based on Newman, Webb, and Cochrane (1995) was used. Newman et al. (1995) developed this content analysis instrument based on Garrison's (1992) five stages of critical thinking and Henri's (1992) cognitive skills. They identify 10 critical thinking categories: relevance, importance, novelty, outside knowledge, ambiguities, linking ideas, justification, critical assessment, practical utility, and width of the discussion. For each category, a number of positive and negative indicators are formulated and most indicators are fairly obvious opposites (Newman et al., 1995). Within the framework of the present study all critical thinking categories and indicators distinguished by Newman et al. (1995) were adopted. For each of the 9 groups, the complete communication in relation to the 4 discussion assignments was analyzed. Two trained coders coded the messages independently. Inter-rater reliability was calculated and found satisfactory for each category of critical thinking.

Results and Conclusion

Through analysis of variance we contrasted students' critical thinking in the experimental labeling condition with the presence of critical thinking in the control condition. In a first step of the analysis, we compared the overall depth of critical thinking. To enable more detailed statements with regard to the differential impact of both research conditions on students' critical thinking in the discussions, in a second step the global measure of overall depth of critical thinking was split up by analyzing the ratios for each critical thinking category and the incidence of the separate critical thinking indicators in the content analysis scheme of Newman et al. (1995). In order to study the depth of critical thinking taking place in each of Garrison's stages of critical thinking (1992), in the third step of the analysis each indicator was related to the stage in which it is most expected.

The results concerning the comparison of both research conditions do not reveal an univocal image favoring one research condition. As to the overall depth of critical thinking no significant differences between the labeling and control condition were found ($F(1, 1515)=0.970$, $p=.325$). Further, the conditions did not differ significantly concerning the discussion of ambiguities ($F(1, 1511)=3.277$, $p=.070$), the width of the discussion ($F(1, 1506)=0.147$, $p=.702$), the introduction of new ideas ($F(1, 1472)=0.306$, $p=.580$) and outside knowledge ($F(1, 1345)=2.358$, $p=.125$), the linking of information ($F(1, 1343)=0.280$, $p=.597$), and the discussion of the practical utility of the shared information ($F(1, 86)=2.057$, $p=.155$). Students in the experimental condition however did significantly outperform students in the control condition with regard to the relevance ($F(1, 1515)=7.454$, $p=.006$) and importance ($F(1, 1515)=3.891$, $p=.049$) of their messages. On the other hand, the control condition attained higher critical thinking ratios for the following categories: justification ($F(1, 1304)=4.738$, $p=.030$) and critical assessment ($F(1, 750)=7.489$, $p=.006$). With regard to Garrison's stages of critical thinking (1992), the analyses reveal that students in the control condition posted significantly more messages focusing on evaluating the applicability of possible solutions to the presented problem ($F(1, 1515)=7.277$, $p=.007$), while students in the knowledge type condition posted significantly more messages focusing on integrating new knowledge with existing knowledge ($F(1, 1514)=4.473$, $p=.035$). Taking these results into account, we cannot conclude that asking students to label their contributions in the discussion has an overall positive impact on their critical thinking. This could be due to the fact that students were not very consistent in their labeling behavior. Since the discussion system does not compel students to attach a label to their contributions, it appeared that only in 49.5% of the cases students in the labeling condition actually tagged their messages by one of the categories reflecting a stage of the progressive inquiry model. Moreover, the results indicate that students' labels were rather one-sided: 40.3% of the tagged messages received the label "my explanation". These results indicate that students probably need more instructions and training before participating in discussions where they have to assign labels to messages. This finding corroborates the research of Jeong & Joung (2007) who found that students without previous training only labeled 52% of their messages correctly.

Apart from the findings that students in the experimental condition were not always consistent in their labeling behavior and relatively one-sided in the selection of a label for a specific contribution, the equivocal results concerning the distinction between both research conditions could be due to the tutor support that the groups experienced as well. Research more specifically indicates that different tutor styles can be distinguished, leading to a diversity of supportive behavior (De Smet, Van Keer, & Valcke, in press). To verify this hypothesis concerning the impact of differential tutor support, the abovementioned analyses of variance were repeated, including tutor variables as covariates in the models. More specifically, the following covariates were included: tutors' participation and presence in the discussions and the extent to which they try to elicit student contributions focusing on identifying a problem, defining it more clearly, exploring the problem and possible solutions, evaluating their applicability, and integrating this understanding with existing knowledge. The results of the analyses of covariance corroborate the significant impact of differential tutor support. Moreover, after correction for the impact of the characteristics of tutors' contributions, a more unambiguous picture of the differences between the research conditions appears. For none of the critical thinking ratios the control condition outperformed the experimental labeling condition. No significant differences were found for the following critical thinking categories: relevance ($F(1, 1507)=1.195$, $p=.139$), width of the discussion ($F(1, 1498)=0.443$, $p=.506$), outside knowledge ($F(1, 1337)=2.181$, $p=.140$), justification ($F(1, 1296)=0.447$, $p=.504$), and utility ($F(1, 78)=0.515$, $p=.475$). Further, the results indicate significantly higher critical thinking ratios for the overall depth of critical thinking ($F(1, 1507)=11.480$, $p=.001$), the importance of the contributions ($F(1, 1506)=15.862$, $p<.001$), the discussion of ambiguities ($F(1, 1503)=9.166$, $p=.003$), the input of new information and ideas ($F(1, 1464)=6.707$, $p=.010$), the linking of information ($F(1, 1335)=5.658$, $p=.018$), and for the critical assessment ($F(1, 742)=5.591$, $p=.018$) reflected in messages in the condition in which students tagged their messages by means of knowledge types. With regard to Garrison's stages of critical thinking (1992), the analyses reveal that students in the knowledge type condition posted significantly more messages focusing on defining the problem ($F(1, 1506)=13.205$, $p<.000$) and on integrating the new knowledge with existing knowledge ($F(1, 1506)=16.725$, $p<.000$).

These results are in line with the suggestion of Jeong & Joung (2007) who claimed that asking students to label their messages could improve argumentation but only under certain circumstances and when additional strategies are introduced. Involving peer tutors in the discussion can be seen as a possible way to make scripting by labeling work.

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Effects of Technology-based Support for Explanation Construction on Learners' Discourse during Design-based Learning in Science

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Abstract: We examine the effects of a software-based approach to scaffolding explanation construction on learners' discussion in a design-based learning environment. The approach consists of having learners collaboratively work around a software-based explanation-construction tool in the context of addressing their design needs during design investigations. We conducted a study where three sets of participants completed a one-week hovercraft unit with the same teacher. We have analyzed the data collected from two sets of participants where one set was facilitated by only the teacher in their explanation efforts and the other set was facilitated by both the teacher and our software called SHADE. Results indicate that participants who used the software engaged in higher quality explanatory discourse by the end of the unit. This research supports the usefulness of a contextualized explanation-construction tool in promoting explanatory discourse.

Introduction

Approaches to enculturating learners into the epistemic practice of explanation construction continue to receive significant attention in educational research because of the recognition that articulating and applying explanations is closely tied to advancing one's conceptual understanding (Coleman, 1998; Sandoval & Reiser, 2004; Vattam & Kolodner, 2006). Our research has investigated the promotion of explanation construction among middle school students learning science in a design-based inquiry environment. We have found that learners' development and their ability to participate effectively in such a practice are heavily dependent on teacher expertise in scaffolding that practice and modeling the discourse of explaining (Ryan & Kolodner 2004). Having noticed that not all teachers have this kind of expertise, we have been seeking technology-based approaches to complement teacher facilitation to help middle-school learners become better scientific explainers (Vattam & Kolodner, 2006). In this paper we will present one example of this approach, a software tool called SHADE (Science of Hovercraft Aided by Designing and Explanation). SHADE's explanation-construction component is connected to a design exploration and investigation component. The explanation-construction tool illustrates and frames, through an external representation, the essential elements of a causal explanation of an observed physical phenomenon.

Our purpose in this study is to investigate the potential of such an explanation-construction tool to overcome some teachers' lack of strong content knowledge and explanation-construction capabilities. Can such a tool, integrated into a design-based learning environment in ways that allow learners to recognize its usefulness, help enculturate learners into becoming better scientific explainers? More specifically, we examine the affordances of SHADE as a collaborative explanation-construction tool for enhancing explanatory discourse and explanation construction in the classroom. Our overall research hypothesis is that (a) by contextualizing explanation in design needs of learners, we can encourage them to want to explain, (b) by contextualizing explanation in design exploration and investigation, learners will get direct experience at explaining their observations, and (c) by employing a representational framework that models explanatory discourse, learners will be scaffolded into generating more conceptually and structurally elaborate explanations during whole-class discussions and presentations.

Background

Learning to formulate explanations is an important aspect of the scientific enterprise (Coleman, 1998). Recent theoretical work supports the view that it is essential to participate in the discourse practices of disciplinary communities to gain a deeper understanding of discipline-specific concepts (Lave & Wenger, 1991; Roth, 2001). Therefore, many inquiry-based learning methods, which seek to place the learners in the role of scientists, face the prospect of dealing with enculturation of their learners into the epistemic practice of scientific explanation.

Although explanation-based interactions affect individual achievement in the context of group learning, research shows that learners will not naturally generate efficient explanations on their own and need support to do so (see studies cited by Coleman, 1998). In our design-based approach to science learning, called Learning by Design (LBD) (Kolodner et al., 2003), teachers enculturate learners into scientific explanation through exposure, experience, and discourse modeling. As learners progress through the LBD unit, learners not only engage in design engineering, but also conduct experiments and collect data from these experiments to inform their future design choices. In the context of presenting their experimental procedure, data and conclusions, the teacher attempts to facilitate explanatory discussion by helping learners focus their comments on explaining their findings in terms of causal mechanisms. In this way, learners are helped with socially constructing scientific arguments.

But our research has also shown that some teachers are not as successful in facilitating scientific explanation as others, especially those who are not as fluent with the science content, as skilled at modeling the discourse of scientific argumentation, or as able at focusing learner discourse on the underlying science concepts (Ryan & Kolodner, 2004).

We have adopted a technology-based approach to complement teacher facilitation in helping middle-school students become better scientific explainers. Our first attempt involved the integration of a software tool called SIMCARS into an LBD unit, *Vehicles in Motion*. SIMCARS included an explanation-construction tool that was designed to be used by learners working in pairs or small groups around a computer in the context of conducting experiments and collecting data. The explanation-construction tool consisted of an explanation template that served as an external discursive representation. A discursive representation (Sandoval et al., 2003) is one that represents elements of a scientific explanation as opposed to, say, simulations which represent a physical phenomenon on a computer. Integration of SIMCARS influenced the *Vehicles* unit in a two ways. First, by situating learners' explanation construction in the activity of experimentation and data collection, it situated their explanation and scientific argumentation in their design needs and in the design space. Second, it distributed the responsibility of scaffolding learners' explanation construction across the teacher and the tool. Learners' inclination to scientifically explain their design investigation findings without expert facilitation suggests that a tool like SIMCARS holds potential to bridge the design-science gap among learners and help at least some individuals develop a better understanding of the content in a less teacher-dependent fashion (Vattam & Kolodner, 2006).

Discursive representations have been a subject of much study in the context of scientific knowledge construction (Bell & Linn, 2000; Sandoval et al., 2003; Scardamalia & Bereiter, 1994; Toth et al., 2002; Vattam & Kolodner, 2006). A majority of those studies, including our earlier SIMCARS research, have focused on individual achievement in the context of group learning. Only some of them have examined the role of such representations as mediational resources (Roschelle & Teaslay, 1995) facilitating collaborative interactions. Suthers & Hundhausen (2002) reported the effect of such representations on learner discourse in the context of within-group collaboration. In this paper, we present a new analysis that explores the influence of discursive representation on learner discourse in the context of inter-group collaboration.

Study

Figure 1: Model hovercrafts from design challenges

Shade: Software design

SHADE software was designed in the context of an LBD-style unit called *Hovering around Tech* (henceforth referred to as "the *Hovercraft* unit"). This unit was developed to teach physics concepts related to working hovercrafts and practices of designers and scientists, all in the context of learners designing and building model hovercrafts and carrying out investigations needed for successful design. The unit was designed such that over the course of a week-long science summer camp (approximately 26 hours), the learners, working in small groups, addressed four successive design challenges that increased in complexity with respect to both functionality and science concepts involved: a balloon hovercraft, a flying saucer hovercraft, a 2-fan hovercraft, and a 1-fan hovercraft (see figure 1 for typical models of each kind).

SHADE was developed to promote specific "explanation-construction" interactions in the classroom culture. Our previous research with SIMCARS suggests that such interactions need to be situated within the context of learners' design needs and design investigations to bridge the design-science gap (Vattam & Kolodner, 2006). Furthermore, the more designs learners explore, the more opportunities there are for such interactions to take place. However, opportunities for exploration in the real world are limited due to time and material constraints. Therefore, there is a need to augment the real-world design environment with a virtual design environment that imitates the real world but in a way that both expands the design space for the learners and also allows for more efficient exploration of the space. Therefore, SHADE incorporates a simulation-based virtual design environment in which learners can explore variations of the four hovercraft designs mentioned above.

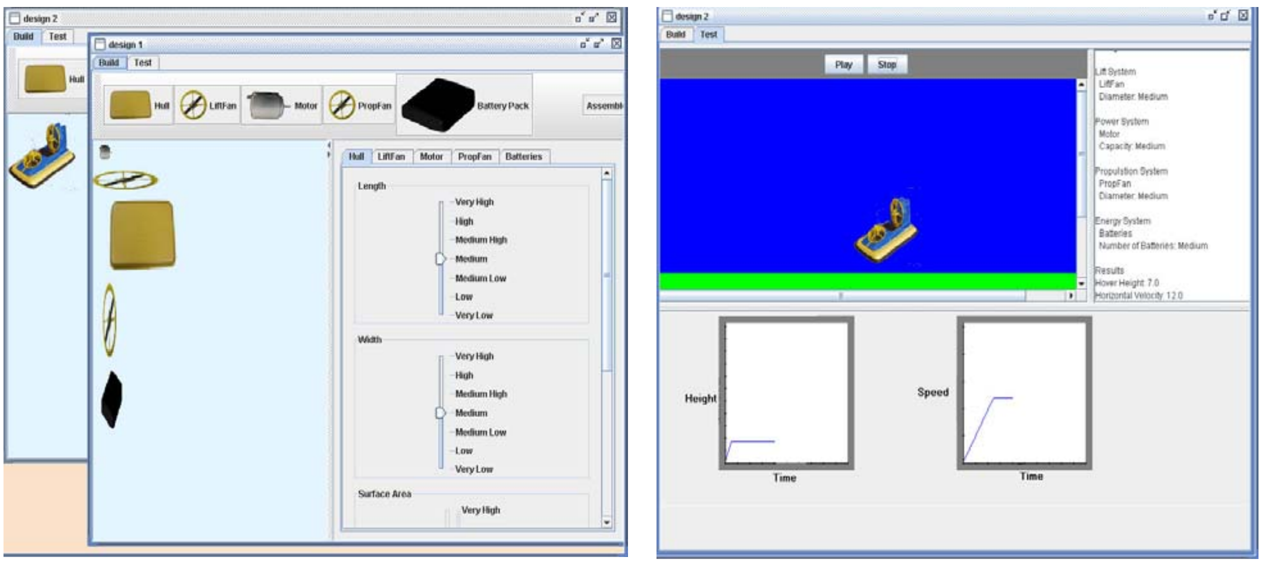
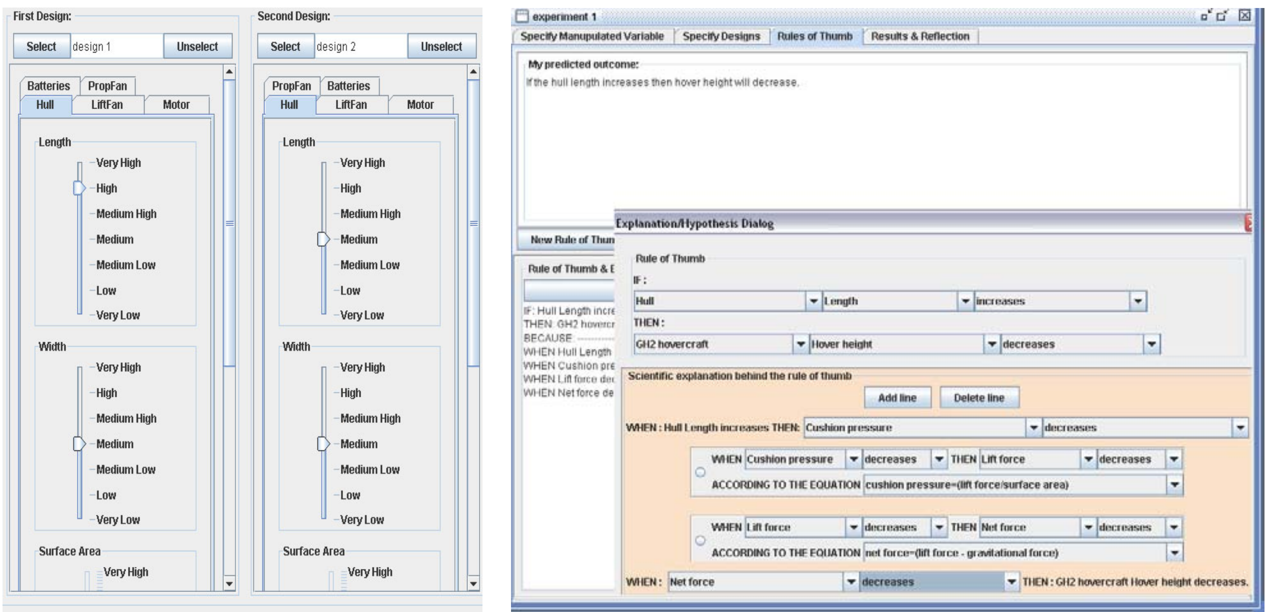


Figure 2: (a) Design area. (b) Test area

To maximize design exploration and to maximize the potential such exploration has for promoting explanation construction, each of the four design challenges was structured in such a way that half the time our learners would be designing and testing real hovercraft models and half the time they would be experimenting with simulated models in the virtual design environment. For instance, in the initial phases of each challenge, they would "mess about" (Kolodner et al., 2003) with real parts and build real hovercrafts. Later, during the design-driven investigation phase, when they are investigating issues important to designing a better-working hovercraft, work would shift to the virtual design environment where they could quickly design new craft and collect consistent data across designs. Finally, when the time came for designing their best hovercraft, they would use what they had learned through the software to design and build a functioning hovercraft that they could race with other groups' crafts.

To facilitate this back and forth movement across real and virtual models, and to help learners transfer knowledge gathered in one medium to the other, we recognized that there had to be correspondence between the real and virtual design environments in terms of how the devices look and behave. The virtual design environment of SHADE has a design area and a test area. Figure 2 (a) shows the design area in SHADE where one can see the correspondence between virtual crafts and the real models depicted in Figure 1. In the design area, users can quickly configure a hovercraft to match their conceptual design by clicking on the various parts and adjusting their parametric values. Figure 2 (b) shows the test area. Learners can test their design in the test area, which animates the behavior of the design along with a graph that plots the hover height versus the hover time. They can also pause and step through the simulation.

An important aspect of design-based investigation is the comparison of many design variations to determine the factors that account for the differences in their behavior. To facilitate this process, SHADE includes a design comparison feature that allows learners to compare multiple designs side-by-side as shown in Figure 3 (a). After choosing the designs for comparison, they have the option of predicting the outcome of running those designs side-by-side, generalizing the prediction as a rule of thumb, and explaining the science behind the predicted outcome. For instance, let us assume that learners were comparing 3 designs (D1, D2 and D3) similar in every respect except that the weight of D3 was greater than the weight of D2, which in turn was greater than the weight of D1. Based on discussions already had in class, learners might predict that "Design 3 will have the lowest hover height." After running the investigation to see if indeed that was true, they could extract a general rule of thumb, "to maximize the hover height, keep the hovercraft weight as low as possible." But the prediction and the rule of thumb alone will not account for the underlying science that would explain them. At this stage, there is an option for learners to launch the explanation-construction tool to back up their prediction or justify their rule of thumb. Figure 3(b) shows the prediction and the rule of thumb that a learner entered and the corresponding explanation entered by the same learner in the explanation-construction tool.



<u>Figure 3:</u> (a) Design comparison. (b) Explanation-construction tool

The Hovercraft unit design and integration of the software

The hovercraft unit was developed to teach physics concepts related to working hovercrafts and the practices of designers and scientists, all in the context of designing and building small hovercraft. The one-week unit was broken down into four design challenges followed by a final presentation to an external audience at the end. For each design challenge, the following sequence of activities takes place:

- **Messing about:** A playful exploratory activity where learners construct a modestly-working device of the kind they will be redesigning later and tinker with it to discover its capabilities and ways of making it better.
- **Whiteboarding:** As a whole class, groups share their experiences and ideas for achieving the challenge and articulate what they need to learn more about. They also discuss what they think they know, and the teacher might present some science content related to what they experienced while messing about.
- **Design-based experiments and poster presentations:** Groups systematically explore design variations to learn more about factors (variables) affecting the working of their designs. When software is integrated, it is integrated into this step in the sequence of activities. Whether or not learners use the software to investigate or run their investigations in the real world, they are encouraged in this step not only to identify trends in their data but also to ask questions about and use science content already discussed to explain those trends. Investigation is followed by a "poster session" (Kolodner et al., 2003) where learners present their findings, the trends (rules of thumb) they can extract from their data, and their best explanations of those trends. This, in turn, may be followed by another presentation of science content by the teacher and then attempts by the whole group to collaboratively construct explanations for each of the trends based on that content.

- **Design best hovercraft:** Based on what they learn from their investigations and from the investigations of others, groups design and build their best hovercraft. Groups also test and compare the performance of their best hovercraft with other groups' hovercrafts. Water races are also conducted sometimes.
- **Gallery walk:** Learners present their design experiences to each other in a gallery walk (Kolodner et al., 2003), asking their peers to help them explain why their designs did or didn't work and suggest ways of fixing the problems. Here again, learners engage collaboratively in explanation construction.
- **Scaling new levels:** Once groups have their best hovercrafts, they are introduced to harder challenges that test the limits of their designs. For example, in the case of the flying saucer, which performs well on smooth floors and carpets, we asked the learners to see if their crafts could hover over grass. In most cases their designs fail, which motivates a new challenge and sets the context for moving on to address that challenge through the next, more sophisticated, type of hovercraft.

Setup

This study was conducted as part of a science summer camp organized by the Center for Education Integrating Science, Mathematics, and Computing (CEISMC) at Georgia Tech and attracted a socio-economically diverse set of rising 7th and 8th graders (ages 13 and 14) from the Atlanta metropolitan area. One teacher collaborated with the researchers to implement the Hovercraft unit three times in three successive weeks. The teacher was neither an expert in the science content nor an expert at design-based learning. However, she was an excellent and energetic teacher in many ways and enthusiastic about learning to use design as a context for science learning. In each week, we had a different set of learners. There were 16, 13 and 18 participants in Weeks 1, 2 and 3 respectively. Participants in Weeks 1 and 3 seemed similar in terms of their background knowledge and overall developmental capabilities, as evidenced in discussions during Day 1 of each week. Participants in Week 2 seemed less motivated and showed less development in terms of their background knowledge and their ability to learn.

Procedure

Based on the natural differences between participants in the three weeks, we have chosen to compare results in Weeks 1 and 3 to learn about effects of integrating the SHADE software into the learning environment. While we had planned a design study where each week we would have participants use an enhanced version of the software, the software was not working well enough in Week 1 to use it. Comparing the results of Weeks 1 and 3 allows us to compare development of explanation capability among participants with similar backgrounds and developmental capabilities, with and without the scaffolding provided by the explanation tool. Participants in Week 1 received support from the teacher to articulate their explanations, and they ran their experiments in the real world and used paper-and-pencil based tools to capture their explanations. Participants in Week 3 followed the same unit with the same teacher but used the software to run experiments and to articulate their explanations. All the sessions were videotaped using two cameras. The two cameras were positioned such that we were able to capture the whole-class interactions during discussions, presentations, lectures, etc.

Findings and Analysis

To understand SHADE's impact on explanatory discourse, we analyzed discourse during whole-group discussions in Weeks 1 and 3 at the beginning of the week, several times during the week, and at the end of the week (see Figure 4).

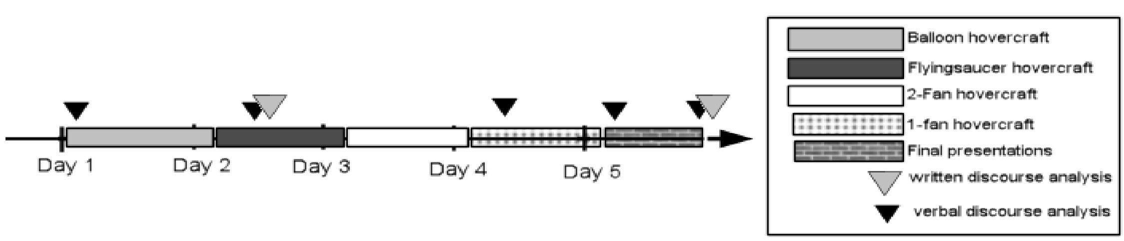


Figure 4: Stages in the unit when discourse analysis was carried out

Discourse analysis at the beginning of the week

Day 1 in both conditions started in a similar fashion with an informal class-wide discussion about what participants already knew about science, engineering, and hovercrafts. Discussions in both weeks were anchored in the question “What does hovering mean?” This discussion was useful in assessing the initial knowledge and explanatory capabilities of participants across the weeks. We found that the discussions during the morning session for both Weeks 1 and 3 were qualitatively similar, consisting of fragmented knowledge of Newton’s Laws and ideas about hovering, with minimal continuity of ideas from one participant to the next. This helped us confirm that the baseline for comparison of the two groups was similar.

Written discourse analysis during the week

The written discourse of the participants in Weeks 1 and 3 was analyzed once during the unit and once at the end. The earlier written discourse was what small groups of learners had written on posters in preparation for “poster sessions” where they presented results of balloon hovercraft investigations. We analyzed the written discourse with respect to its form, content, and correctness.

Week 1

(1) ***“****the larger the air, the longer the hovering time*
Why? Because the air is the power.”

(2) ***“****The larger the balloon, the longer it hovers and the higher it goes.*
Why - because there is more air that comes out of the balloon and it goes longer.”

(3) ***“****The smaller the nozzle, the higher the H[over]T[ime]. The larger the nozzle, the higher the H[over]H[eight].*
Why: when the air passes through a smaller nozzle, the air is more concentrated & blows at a steadier weight, and air passes through a larger nozzle a bust of air lifts the H[over]C[raft] height.”

Week 3

(1) *“If hovercraft has a smaller diameter, it will less surface area and a greater hover height.*
IF: CD diameter decreases
THEN: Balloon hovercraft [hover height] increases
BECAUSE:
WHEN CD diameter decreases THEN lift force increase
WHEN lift increases THEN Balloon hove[r height increases]”

(2) *“IF: Nozzle Diameter decreases,*
THEN: Balloon Hovercraft Hovertime increases
Because…
WHEN: Nozzle diameter decreases THEN [Lift] Force decreases
WHEN: Lift force decreases THEN Balloon hovercraft hover time increases”

Looking at the representative explanations above, we see that Week 3 groups structured their explanations as “if X then Y, because when X then A, when A then B … when C then D, and when D then Y”. The structure of explanations of Week 1 groups, on the other hand, varied from “since X therefore Y” to “X because Y, and Z”. We think the structure of Week 3 explanations was better because participants modeled it on the cause-linking framework modeled for them in the software. When we look at the content of written discourse, the Week 3 groups used more intermediate causal concepts such as net force and lift force in their explanations than did Week 1 groups. We also see that in Week 1, participants typically provided only one-level explanations. As far as correctness is concerned, groups in Week 3 show more correctness. But, that cannot be attributed to SHADE alone because the teacher had improved her understanding of the concepts by Week 3. Therefore, she might have been less misleading in Week 3 than in Week 1. Therefore, we do not take correctness into account in our analysis.

Verbal discourse analysis during the week

We analyzed verbal discourse from 5 whole-class discussions during each week on days 1, 2, 4 and 5 (see Figure 4). The following is an example of verbal discourse analysis of the data gathered from Weeks 1 and 3.

The context for this verbal discourse was the balloon hovercraft challenge, the same one in which the above written discourse analysis was carried out. Groups were asked to investigate ways of making a hovercraft using balloons, bottle caps, and CDs. In both weeks, within thirty minutes, most groups had grasped the techniques needed to assemble a device and had put together a basic working hovercraft. After demonstrating their crafts to each other, the teacher reviewed the scientific method and presented the nomenclature of a hovercraft, including hull, air cushion, cushion pressure, power system, and lift system. It was at this point that discussion during the two weeks diverged. During Week 1, participants conducted design investigations in the real world, and during Week 3 participants used SHADE to conduct design investigations and to (optionally) provide explanations during those investigations. In the poster session that followed in both weeks, groups were encouraged to include results in their posters along with appropriate written explanations. Teacher provided help as needed in both weeks to help participants complete this task. We analyzed the verbal discourse of participants presenting their posters and verbal discourse of any accompanying whole-class discussions.

Our analysis shows that the verbal discourse of participants in Week 1 contained impoverished explanations with respect to science content and focused primarily on the designed artifact. The verbal discourse of participants in Week 3, on the other hand, were more sophisticated and mimicked the explanations that they had articulated using SHADE. A snippet from typical verbal discourse from Week 1 and Week 3 are compared below:

Typical Week 1 explanation
Student: *If I change the size of the balloon it will hover longer.*
Teacher: *… change the" if" statement to make it better*
Student: *If I increase the balloon…*
Teacher: *Good, if I increase the balloon size then it will hover longer.*

Typical Week 3 explanation
Student: *If the lift force is greater than the gravitational force then the net force will be directed upward, but if the gravitational force is greater than the lift force then the net force will be directed downward and the hovercraft would not move.*

A full analysis of the same data shows that the best Week 1 discourse was equivalent to the typical Week 3 discourse, and that the best Week 3 discourse was significantly better than the best Week 1 discourse as depicted below:

Best Week 1 explanations
(1) ***Student1:*** *Because adding weight to the hull is going to push more gravity down and it is going to push the air cushion down and have less air cushion"*

(2) ***Student2:*** *With every action there is an equal and opposite reaction…[so] air under the hull must overcome gravity*

Best Week 3 explanation
Student: *If fan diameter increases then flying saucer hovercraft hover height increases because, when fan diameter increases then the cushion pressure increases. When cushion pressure increases then lift force increases. When lift force increases then net force increases. When net force increases then flying saucer hovercraft hover height increases.*

Discourse analysis towards the end of the week

On the last day of the week, small groups presented their experiences in the camp to an external audience including their family members. The latter part of the morning session of the final day was dedicated to preparing posters for their presentations. Student groups were given a list of topics to choose from for their posters. They were also free to choose their own topics. The content of posters and verbal presentations of groups in Weeks 1 and 3 were compared to analyze the differences in learners' discourse towards the end of the unit. We classified these posters into four categories based on their function, as depicted in Table 1.

Table 1: Classification of final posters and their sample contents

Poster Type	Sample contents
Recommendation posters: Their function was to communicate to the audience how to build a good hovercraft of a particular type. Typically, they contained a list of recommendations with or without associated explanations. Sometimes, the recommendations were captured implicitly in the form of Rules of Thumb.	*"**the best flying saucer needs:** maximum hover height, a light weight structure, … , a sturdy body **Results from tests:** We have concluded that a flying saucer hovers best with 1 battery pack because with 2 ... we concluded that a hovercraft (flying saucer) hovers higher when it has a bumper on the bottom.... Our last conclusion is that 30 grams is a good weight for a flying saucer."*
Investigation posters: Their function was to communicate the results of the experiments conducted to understand the effect of a particular variable (e.g., hull weight, surface area) on the overall performance of the hovercraft. They captured the outcome of the experiments in terms of rules of thumb.	*"ROT: if the surface area increases then the hovercraft hover height decreases. Why? If the surface area increases, the cushion pressure beneath the hovercraft will decrease because it will have to support a larger area…"*
Comparison posters: Their function was to communicate the comparison of different designs. They usually contained	*"**Differences in the 1 fan hovercraft and the 2 fan hovercraft** **GH1:** … one fan is used … to give the craft lift and to push it forward … a ramp is us to direct the air flow under & behind the craft.*

the decisions behind compared designs and any trade-offs with or without explanations.	***GH2:*** *… one fan pushes air down… 2nd fan is placed at the back … pushes air backwards causing the craft to go forward.* *…* ** The one fan is lighter, allowing the hovercraft to go higher. This is because …* ** The one fan isn't as forceful as a craft with two fans….* ** The hovercraft with 2 fans is heavier than the hovercraft with 1 fan but the extra power makes up for the extra weight…"*
Description posters: Their function was to communicate description of an object of interest (example – hovercraft, skirt). Typically, they contained description of systems or subsystems in terms of their structural elements and also how they worked. In the context of describing how it works, participants explained the science behind hovercraft design in some cases. Interestingly, description posters can only be found in Week 3.	*"**What in the world is a skirt?*** ** How does it contribute to a hovercraft?* *It increases the cushion pressure underneath the hovercraft …* ** What makes a good skirt?* *Light-weight durable, …* ** Difference types of skirts!* *1. Self-inflatable: won't fold under the hovercraft...* *2. Bumper Reinforcement: bumper material … is put inside…* *3. Tape reinforcement: … also put in the skirt to make it sturdier."*

To analyze the final posters and presentation, we first counted the total number of statements made that warranted an explanation, including recommendations and rules of thumb. We rated these statements according to simple statements (Type 1), statement with rudimentary explanations (Type 2), and statements with good explanations (Type 3). For example:

> **Type 1:** *"...small [balloon] - has the least power, medium [balloon] - has medium power, large [balloon] - has the most power…"*
> **Type 2:** *"…if the surface area increases then the hovercraft hover height decreases… [because]... the cushion pressure beneath the hovercraft will decrease…."*
> **Type 3:** *"… [Skirt] contributes to the hovercraft … increases the cushion pressure underneath the hovercraft causing the lift force, net force, and hover height to increase."*

Good explanations (Type 3) contained coherent causal explanations. Rudimentary explanations (Type 2) contained either mere reproduction of formulas without showing any understanding of the formulas or simple explanations without intermediate causal concepts. Simple statements (Type 1) are statements without justification of any sort. Type 3 statements are given the highest rating and Type 1 the lowest.

In Week 1, posters and presentations mostly contained Type 1 and Type 2 statements. The following Table 2 captures the findings from Week 1. As one can see, most statements are Type 2 (8 out of 13, 61.53 %).

Table 2: Results of analysis of Week 1 posters and presentations

	Title	Poster category	Type 1	Type 2	Type 3
A	Hull weight	comparison	0	0	1
B	Surface area	comparison	1	0	0
C	Motor power	comparison	1	2	0
D	1 fan vs. 2 fans	comparison	0	2	0
E	Best flying saucer	recommendation	2	2	0
F	Balloon hovercraft	recommendation	0	2	0
		Total = 13	4	8	1

In Week 3, posters and presentations had significantly fewer Type 1 statements and contained an equal number of Type 2 and Type 3 statements. Table 3 captures the findings from Week 3. Most statements are either Type 3 (5 out of 11, 45.45 %) or Type 2 (5 out of 11, 45.45 %).

Table 3: Results of analysis of Week 3 posters and presentations

	Title	Poster category	Type 1	Type 2	Type 3
A	Difference in 1 & 2 fan	comparison	0	0	2
B	The effect of weight	comparison	0	1	0
C	Surface area	comparison	0	0	1
D	Best flying saucer	recommendation	0	2	0
E	Best balloon	recommendation	1	1	0
F	What's a skirt?	description	0	1	1
G	Hovercraft 101	description	0	0	1
		Total = 11	1	5	5

The consolidated results in Table 4 show the overall differences between Weeks 1 and 3 with respect to the statement types. While 30% of the statements in Week 1 were of Type 1, only 9% were of Type 1 in Week 3. While only 7% of explanations in Week 1 were of Type 3, almost half (45%) in Week 3 were of Type 3.

Table 4: Consolidated results comparing posters and presentation findings across Weeks 1 and 3

	Type 1		Type 2		Type 3	
Week 1	4/13	30.76 %	8/13	61.53 %	1/13	7.69 %
Week 3	1/11	9.09 %	5/11	45.45 %	5/11	45.45 %

Discussion

This study sought to explore the affordances of SHADE as a collaborative explanation-construction tool for enhancing learners' explanatory discourse and explanation construction in the classroom. We hypothesized that the learners who used the explanation-construction tool would engage in better explanatory discourse by the end of the Hovercraft unit in comparison to learners who did not use the tool, even if all received similar teacher support throughout the unit. Our results support this claim because both written and verbal discourse of participants who used the explanation-construction tool in Week 3 was significantly different from that of participants who did not use the tool in Week 1. Specifically, changes were noticed in three areas. First, participants in Week 3 felt the need to explain more. More of their claims and findings were communicated with causal explanations when compared to participants who did not use the tool. Second, participants from Week 3 maintained a more coherent structure in their explanations consistently across groups throughout the unit. Third, the content of explanations from Week 3 was more elaborate and contained more intermediary causal concepts (e.g., lift and net force) compared to Week 1.

How did SHADE impact the learners? The participants in Weeks 1 and 3 had similar knowledge and capabilities at the start of their hovercraft experiences, but the teacher knew a bit more about hovercraft science and design-based learning by Week 3. So there are two possible reasons why the learners in Week 3 might have performed better: the teacher's increased understanding might have influenced the learners' understanding and capabilities and/or use of the software might have been responsible. We have been able to rule out the influence of the teacher because while our analysis showed that there was some improvement in the teacher's understanding of science concepts by Week 3, we did not see a significant impact of this on either her explanatory discourse or her methods of teaching. This suggests that use of SHADE's explanation-construction tool was primarily responsible for the better quality of explanatory discourse among Week 3 participants. Our explanation for the increased number of explanations in Week 3 is that situating SHADE's explanation-construction tool in the context of design investigations gave participants practice *both* in explaining observations and also in identifying opportunities to explain. A possible explanation for the differences in the form and content of the explanations between Weeks 1 and 3 is that learners who received structured explanation support in SHADE developed better conceptual frameworks in which to organize the specific concepts they learned, and the external discursive representation gave participants a better understanding of the form of a good explanation. This account is in line with the foundational literature we drew on in SHADE's design which suggested that explanation support would provide specific guidance about the nature of scientific explanations.

How did SHADE impact the teacher? Although the software had an equal potential to impact the teacher's discourse, SHADE influenced learners more than the teacher during this study. That can be explained by the fact that the teacher did not use SHADE at all. The constant presence of researchers during all the 3 weeks did not necessitate the teacher's use of the tool to integrate it into her teaching. Under normal circumstances, though, we can expect that the teacher would use SHADE before and during the implementation of a unit. This has the potential to influence teachers' discourse as well, in the same way that the software usage influences the learners. We also expect that this change in teacher's discourse will be an additional influence in enculturating the learners into becoming better scientific explainers. A useful extension of this study would combine the kind of analysis presented here with discourse analysis of teachers in the classroom after they actively use and integrate the SHADE software.

A software tool like SHADE makes a difference in how learners and teachers engage in collaborative learning to become better scientific explainers. Our in-depth discourse analysis suggests that external discursive representations embodied in the explanation-construction tool affect collaborative knowledge construction. Our results have implications for learning and instruction in design-based learning environments. Often, teachers' lack of expertise in facilitating knowledge construction in such environments hampers development of scientific understanding among learners. Our hypothesis is that enculturating learners and teachers into explanation construction in the context of design-based investigations promotes such scientific understanding through collaborative knowledge construction, and our results suggest that a tool like SHADE that models appropriate discourse has an important role to play as a mediational resource in facilitating collaborative interactions in the classroom.

Acknowledgements

This research was supported in part by a grant from the National Science Foundation. We wish to thank Eric Goldstein, Tony Docal and Megan McCollum for their support in this research effort.

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The Student Becomes the Master: Integrating Peer Tutoring with Cognitive Tutoring

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Abstract: Combining peer tutoring with an intelligent tutoring system (ITS) holds the promise of augmenting the current benefits of the ITS. We designed and implemented a peer tutoring approach as an addition to the Cognitive Tutor Algebra (CTA), an ITS for high school algebra. We then used 30 students to evaluate the potential of the peer tutoring addition to increase learning. Although students learned and interacted positively, peer tutors lacked the necessary expertise to adequately help their tutees.

Introduction

Combining collaborative activities with intelligent tutoring might be an effective way of increasing student knowledge. The guided problem-solving provided by an ITS is effective but limits student construction of knowledge, while collaborative activities increase the potential for the acquisition of deep knowledge but do not always provide sufficient guidance for students. Our work integrates collaborative learning with an ITS using a peer tutoring framework, with the goal of allowing students to tutor each other through the interface of an ITS, supported by both cognitive and collaborative tutoring. However, implementing a peer tutoring script within the context of an existing ITS may not require much computer tutoring to be effective, for two reasons: Students who have used the ITS already have a mental model for how the cognitive tutoring works in the ITS, making it easier for them to assume the tutoring role, and as the student interaction is structured through the interface of the ITS, it might be easier to implement script elements than if students were interacting face-to-face. Additional cognitive and collaborative tutoring would only be necessary if students do not comply with the script. Therefore, our first step is to implement a baseline peer tutoring condition within the context of an existing ITS: the Cognitive Tutor Algebra. We use the interface of the ITS to structure the interaction between the students, but we do not provide hints and feedback to the students as they collaborate. The effectiveness of this condition at increasing learning will indicate whether and how to provide adaptive support.

Script Design and Implementation

We incorporated elements of previous successful peer tutoring scripts into our intervention. Peer tutoring has been shown to be effective when students exhibit certain behaviors. Asking specific questions, receiving elaborated explanations, and using those explanations constructively have been correlated with tutee learning (Webb, Troper, & Fall, 1995). Students learn from being tutors if they prepare ahead of time (Fantuzzo, Riggio, Connelly, & Dimeff, 1992), monitor skills being acquired (Fuchs et al., 2003), and provide their partners with elaborated explanations (King, Staffieri, & Adelgais, 1998). Biswas, Schwartz, Leelawong, Vye, and the TAG-V (2005) identified three aspects of learning interactions that seem to explain the benefits of learning by teaching: students take responsibility for, reflect on, and structure their knowledge.

In our peer tutoring script, students are given a task like "Solve for x," for an equation like "ax + by = c." Students go through two phases: a preparation phase and a collaboration phase. In the *preparation phase*, peer tutors are given a chance to practice with the material ahead of time by solving problems using the CTA. They use an equation solver tool to manipulate the equation, and are given immediate feedback from the cognitive tutoring component of the CTA when they make a mistake. They can also ask for a hint from the CTA at any time. As they solve the problem, they are given feedback on their progress through a skillometer, which contains bars that represent their skills and change in value with correct and incorrect student actions. During the *collaboration phase*, students are grouped into same-gender pairs of similar abilities and collaborate at different computers, taking turns being peer tutors and peer tutees. Peer tutees solve the same problems as their tutor solved in the preparation phase, using the same interface. Peer tutors can see their peer tutee's actions, but cannot solve the problem themselves. Instead, they are given a printout of their own answers to that particular problem, and take the role of the cognitive tutor. They can mark the peer tutee's actions right or wrong, and adjust the values of the tutee's skill bars. There is also a chat tool, where tutees can ask questions and tutors can give explanations.

We added two additional activities to extend the script and guide students in their interaction. First, during the preparation phase, we gave students questions to prepare them for the collaborative challenges of tutoring as well as the cognitive ones (e.g., "A good question is specific. It asks why something is done, or what would happen if the problem was solved a certain way. What is a good question to ask about the step you chose in Question 2?"). Second, we gave students three additional reflection questions after they had just finished tutoring a problem (e.g., "What was the best question asked by the tutee? If the tutee didn't ask any questions, what was a good question he/she could have asked?"). We implemented the peer tutoring within the context of a more general collaborative framework added to the Cognitive Tutor Algebra (CTA).

Script Evaluation

We compared two conditions, one in which students tutored each other using the CTA interface by following the preparation and collaboration phases (the *tutoring* condition), and one in which students tutored each other using the CTA interface and were given the additional collaborative instruction described in the previous paragraph (the *tutoring+reflection* condition). We hypothesized that peer tutoring would increase student learning in both conditions, but giving students additional instruction would enhance the effects of the peer tutoring. See Table 1 for a description of the experimental procedure. To assess student learning we used a counterbalanced pretest and posttest, each containing 8 questions drawn from the same unit as the treatment questions.

Participants were 30 high-school students from two first-year algebra classes at a vocational high school. Both classes were taught by the same teacher. Due to the disruptiveness of students in the same class using different interventions, we used a between-class manipulation. The class with the most participants was assigned to the tutoring+reflection condition. Only 14 participants participated in all phases of the study (pretest, preparation for tutoring, peer tutoring, and posttest): seven in the tutoring condition, and seven in the tutoring+reflection condition. Unfortunately, there were significant between-class differences: students in the tutoring+reflection condition were working on a significantly lower unit in the Cognitive Tutor Algebra prior to the study (Ms = Unit 8.3 and Unit 11.6, SDs = 1.25 and 2.76, $F(1,12) = 8.22$, $p = .01$).

Table 1. Experimental procedure. Differences between conditions are highlighted by *italics*.

Day	Activity	Time	Tutoring Condition	Tutoring + Reflection Condition
1	Pretest	10 min.	- pretest on domain knowledge	- pretest on domain knowledge
2	Overview	15 min.	- overview of tutoring interface	- overview of tutoring interface
2	Preparation Phase	40 min.	- students solve the problems they will be tutoring	- students solve the problems they will be tutoring - *students answer reflection questions*
3	Collaboration Phase	50 min.	- students tutor each other	- students tutor each other - *students answer reflection questions*
3	Posttest	10 min.	- posttest on domain knowledge	- posttest on domain knowledge

Results

We scored the pretests and posttests on a 5 point scale. We then conducted a two-way (condition x test-time) repeated-measure ANOVA, with test-time as the repeated measure. Posttest scores were significantly higher than pretest scores in both the tutoring and the tutoring+reflection condition ($F(1,12) = 15.25$, $p < .002$, $\eta^2 = 0.56$), but there were no significant differences between conditions, and no interaction (see Table 2). To further examine what occurred during the collaboration phase we turned to log data and notes from classroom observation. During peer tutoring, students appeared engaged, and did exhibit many of the positive collaborative behaviors that we were attempting to encourage with our script and that have been shown to correlate with knowledge construction and self-reflection. However, we observed that peer tutors struggled to provide tutees with answers, and did not connect the preparation that they had done with the collaboration phase. For instance, they often did not consult their answer printouts when they did not know the next problem step and thus had to rely on teacher assistance to solve a problem. As a result, tutees skipped problems without completing them correctly. This undesirable behavior differed between the two conditions (see Table 2). Students in the tutoring condition attempted more problems than students in the tutoring+reflection condition, and appeared to complete more problems as well. The average number of problems completed by dyads in the tutoring+reflection condition was low; students in this group took an average of 11 minutes to complete a single problem, compared to a 6 minute average in the tutoring condition. Students in the tutoring condition tended to skip problems they could not solve, completing less than 60% of the problems they attempted. Immediately before skipping a problem, students would generally state their inability to solve it, “I don’t know how to do this one,“ or their lack of motivation, “Just do something and I’ll agree or something.” If students skip problems, they may not learn how to solve difficult problems. However, if they do not complete many problems, they may not be sufficiently exposed to all the skills involved in the unit, and will be given fewer opportunities to master them.

Table 2. Attempted problems and interaction data for the two conditions

	Pretest Score		**Posttest Score**		**Problems Attempted**		**Problems Completed**	
Condition	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Tutoring	31.1	25.4	45.8	31.8	14.2	8.47	8.4	5.13
Tutoring + Reflection	22.9	15.3	42.8	22.0	5.8	3.11	4.4	0.89

Conclusion

Although students learned as a result of the peer tutoring, we did not find that the condition with additional tutoring instruction learned more than the condition without additional instruction. Instead, many students had difficulty following the peer tutoring script effectively. Students in the tutoring group tended to skip past problems they could not solve, while students in the tutoring+reflection condition completed fewer problems than students in the tutoring group. Increasing the number of problems that students are able to correctly complete while collaborating should improve student learning, because students will be given more of an opportunity to master the skills required by different problems. Adding adaptive feedback should allow peer tutors to more effectively and accurately help their partners.

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Acknowledgement

This research is supported by the Pittsburgh Science of Learning Center, NSF Grant # 0354420.

Thinking Hard Together: the Long and Short of Collaborative Idea Generation in Scientific Inquiry

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Abstract: Idea generation is a cognitive process that plays a central role in inquiry learning tasks. This paper presents results from a controlled experiment in which we investigate the affect on productivity and learning from doing idea generation tasks individually versus in pairs, with versus without automatic support from a virtual brainstorming agent called VIBRANT. Our finding is that individuals brainstorming with VIBRANT produced more ideas than individuals who brainstormed with a human peer. However, an additional finding is that while brainstorming in pairs lead to short term process losses in terms of idea generation, with a corresponding reduction in learning in terms of pre to post test gains, it produced a productivity gain for a subsequent distinct individual inquiry task. Furthermore, automatically generated feedback from VIBRANT improved learning during idea generation but did not mitigate the process losses that were associated with reduced learning in the pairs conditions.

Introduction

Inquiry as an approach to learning typically consists of such activities as exploring the targeted phenomena, formulating and asking questions, making discoveries, achieving deeper understanding, and fulfilling intellectual curiosity. Virtually every inquiry activity begins with "asking questions" after which students may be requested to move on to "finding answers" or "testing the solutions", and subsequently, "asking better questions". *Idea generation* is of central importance in this process.

We are conducting our investigation in connection with the Debris Flow Hazard task (DFH), which is an example of an inquiry problem used by science educators as an assessment of creative problem solving ability (Chang & Weng 2002). The DFH task is defined by the following two idea generation prompts: *"What are the possible factors that might cause a debris-flow hazard to happen?"*, and subsequently, *"How could we prevent it from happening?"* Notice that the goal for students here is not to select and then apply a known procedure for solving a well defined problem. In contrast, the purpose here is to let students work first to define the problem and then creatively formulate the candidate problem solving steps/options. Beyond offering students the opportunity to generate possible solutions to problems, these tasks offer students the opportunity to weigh and balance trade-offs between alternative solutions since there is no single correct solution to the problem.

Based on cognitive theories of associative memory, idea generation can be viewed as the process of building on the retrieval of information encoded in a stimulated portion of a semantic network stored in one's long-term memory (Brown & Paulus, 2002; Dugosh et al., 2000; Nijstad & Stroebe, 2006). When students have access to domain facts either through their own memory or provided externally through access to learning resources, students may engage in a constructive process to bridge instances of domain facts on the way towards generating ideas (Brown & Paulus, 2002). For example, students may have access to the following two domain facts: (1) Debris flow refers to the mass movement of rocks and sedimentary materials in a fluid like manner. And, (2) There are many typhoons, or hurricanes, in Taiwan in the summer time. Students may then make the following two bridging inferences: (1) Heavy rain implies the presence of a massive amount of water. And, (2) The presence of a massive amount of water may lead to erosion or the movement of rocks in a fluid like manner. They may then generate the following idea: "Typhoons may be a factor leading to the occurrence of a debris flow hazard." As students are generating these bridging inferences, they are elaborating their mental representation of the basic facts they are building on. This process of building bridging inferences and subsequently elaborating mental representations is similar in many ways to the process of self explanation (Chi et al., 1994). In the learning sciences, self-explanation has been shown to be an effective learning process. Thus, through this constructive idea generation process, we expect to find a relationship between idea generation and learning much like the one that has been shown in many contexts between self-explanation and learning, and in fact we did find such a relationship, which we discuss below.

While idea generation in groups is purported to be more effective than idea generation for individuals, it is a well known problem that when groups engage in idea generation together, a phenomenon referred to as *process loss* occurs. In particular, it has been repeatedly demonstrated that a group that is interacting while doing idea generation together may not always perform better than a collection of non-interacting individuals whose contributions are simply pooled afterwards (i.e., nominal groups), both in terms of the quantity and quality of unique ideas, and in fact may sometimes perform significantly worse (Hill, 1982; Diehl & Stroebe, 1987; Nijstad & Stroebe, 2006). Often inquiry learning tasks such as the DFH task are done collaboratively in the classroom. To the extent that learning in inquiry tasks may come from the constructive process of generating ideas, we expect that factors that negatively affect idea generation productivity, such as the presence of evaluative statements (Dugosh et al., 2000) or exposure to instances of ideas that are close to the current idea generation focus (Nijstad & Stroebe, 2006), will also have a negative effect on learning from inquiry tasks where idea generation is involved. As we discuss below, we did find such a pattern in our data, which argues that the phenomenon of process losses in idea generation is a problem that should be taken seriously by learning scientists. Nevertheless, learning in idea generation tasks may arise from multiple different mechanisms, not only from the idea generation process per se. For example, while evaluative statements may inhibit productivity in idea generation, they count as a form of transactivity in collaborative discourse, which shows that group members are attending to one another's contributions and making explicit links between their contributions and those that came before. Supporting such behavior has been shown in other work to support learning (Weinberger et al., 2005).

While much research has been done separately on learning from inquiry tasks in the learning sciences community and the problem of process losses in connection with group idea generation in the social psychology of group work, in this paper we bring these two lines of research together to explore a particular question: How do the process losses that are a well known problem for group idea generation impact learning from inquiry tasks? And furthermore, how can we support learning by mitigating these process losses? Or do we gain more in terms of learning by enhancing other processes at work that may lead to learning even if they inhibit idea generation? In the remainder of this paper we formally explore the connection between learning and idea generation in inquiry tasks through an experimental study. While the results show that even with automatic idea generation support, we still see evidence of process losses connected with a loss in learning, we do see a positive effect on learning of the automatic support mechanism we introduce. Furthermore, we find a positive impact of collaborative idea generation on preparation for a subsequent idea generation task.

Hypotheses and Model

The hypotheses underlying our investigation grow out of the social psychology literature on creativity and group brainstorming as well as the cognitive science literature on associative memory and collaborative learning. The model presented in Figure 1 depicts the hypothesized causal links between interventions (i.e., whether students worked with feedback from the VIBRANT agent or not, and whether they worked in pairs or individually), mediating variables (i.e., cognitive stimulation and social interaction), and dependent measures important in inquiry learning tasks (i.e., productivity in idea production and learning). In the figure, a "+" symbol denotes a positive influence imposed by the node at the initial end of the arrow on the node at final the end of the arrow, while a "++" symbol represents a qualitatively stronger positive influence, and a "-" symbol denotes a negative influence. Circled numbers are included to enhance clarity. Link (a) represents the positive effect of priming stimuli on associative memory activation (Brown & Paulus, 2002; Dugosh et al., 2000). Link (b) denotes the potential learning benefit of knowledge construction (analogous to the process of self-explanation) triggered by the idea generation process (Chi et al., 1994). Link (c) is an inhibitory influence on idea generation, possibly due to a diversion from pure idea generation by evaluative conversation or elaboration, or exposure to instances of ideas too similar to the current focus of idea generation (Nijstad & Stroebe, 2006). Link (d) represents a predicted positive influence of interaction on learning, consistent with reported advantages of collaborative learning (e.g., Weinberger et al., 2005).

From this model, we derive four specific hypotheses that we explore subsequently in an experimental study: (1) Working in pairs will have a differential effect on productivity and learning such that students in the pairs condition will be less productive in their brainstorming but may still learn more. (2) Working with the support of the VIBRANT agent, which provides stimulation in the form of reference to general categories of ideas, will be more effective for stimulating idea production than working with a human peer to the extent that human peers primarily provide concrete instances of ideas rather than general categories of ideas (Nijstad & Stroebe, 2006). (3) Feedback during problem solving supports learning, thus we hypothesize that students working with the VIBRANT agent will evidence more domain learning than students in the no support conditions (Bangert-Drowns et al., 1991). (4) Transactive social interaction supports the acquisition of multi-perspective knowledge (Weinberger, 2003), thus we hypothesize that students in the pairs condition will be more effective at a subsequent idea generation task that builds on ideas discussed in the first brainstorming task.

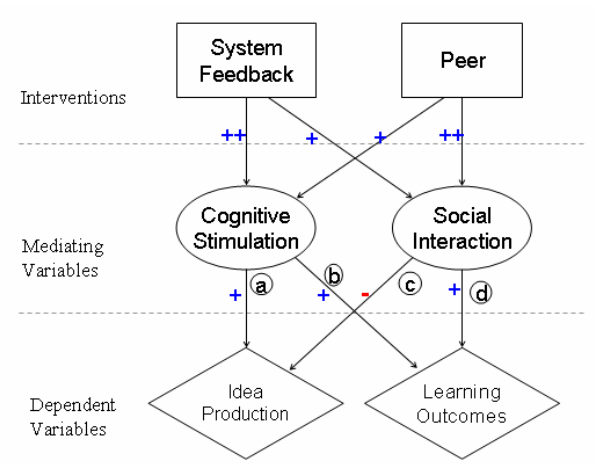

Figure 1. An influence diagram depicting hypothesized causal connections between interventions, constructs and outcome measures.

Method

Experimental Design

In order to test our hypotheses, we conducted an experiment in which students participated in a brainstorming task in an educational context. The Debris Flow Hazard (DFH) task, which is the brainstorming task we selected, has been designed by science educators to engage students in scientific inquiry in the area of Earth sciences (Chang & Tsai, 2005). The learning objective of this task is to make concepts related to geology, agriculture, and urban development concrete for students as they grapple with the manner in which these very different types of factors interact in real world scenarios. However, it is more similar in its cognitive demands to other idea generation tasks used in studies of group dynamics than typical collaborative learning tasks such as mathematics problem solving or collaborative writing. Thus, the specific properties of this task make it particularly appropriate for beginning to explore the separate and joint effects of cognitive and social factors on the productivity and pedagogical value of brainstorming activities. We manipulated whether brainstorming took place as an individual or pair activity and whether feedback was offered or not, both as between subjects factors. Thus, the experiment was a 2 (individual brainstorming vs. pair brainstorming) X 2 (no system support vs. system support) factorial design resulting in four experimental conditions, which are referred to in the remainder of the paper as IN (Individual-No support), IS (Individual-System supported), PN (Pair-No support), and PS (Pair-System supported).

Experimental Infrastructure

In order to implement the four conditions in a way that maintains maximal consistency across conditions, we built our experimental infrastructure on top of a well known instant messaging (IM) service over the Internet, Microsoft Network's MSN messenger (msn.com). Due to the popularity of this IM service with the target user population, using an MSN-based client also lessens potential concerns of software difficulty or novelty effects.

We adapted an existing brainstorming feedback agent called VIBRANT (Wang et al, 2006) to provide prompts in response to conversational behavior in the two system supported conditions. In order to be adapted to a specific task, VIBRANT must be provided with an idea hierarchy at multiple levels of abstraction. In our domain idea hierarchy, the top node representing the entire DFH task is first broken down into 5 general topic areas including geology (e.g., shale rock area), agriculture (e.g., having shallow-rooted economic plants which cannot solidify the soil mass as much as original forests), influences caused by other natural phenomena (e.g., typhoon and rainstorm which break the hydraulic balance), urban development (e.g., building houses at a potential dangerous slope), and social factors (e.g., improper environmental policy). Each subtopic is further broken down into specific idea nodes. A total of 19 specific idea nodes are included. Feedback messages are attached to the nodes of the idea hierarchy both at the general topic level and the specific idea level. Similarly, at the specific idea level, prototype expressions of the related idea collected in previous studies involving the DFH task are attached to idea nodes. In this way, student conversational contributions can be matched to nodes in the hierarchy by matching the text of their contribution to the associated prototype texts using a simple semantic similarity measure.

The feedback provided by VIBRANT consists of two parts. The initial portion, which we refer to as the *comment*, acknowledges the idea that matched, and how it fits or doesn't fit into the hierarchy. The second portion, which we refer to as the *tutorial*, offers a hint for thinking about a new contribution. Feedback messages are constructed by concatenating a selected comment with a selected tutorial. For example, if the student has contributed the idea "deforestation", the system will acknowledge this with the following comment, "Good, you seem familiar with the effects of excessive urban development." A next focus for brainstorming, which coherently follows from this would be more discussion related to urban development, for example "Can you think of a farming practice motivated by economic concerns that may increase the risk of a debris flow hazard?" VIBRANT never offers students specific ideas. Instead, the hints offered by VIBRANT are more similar to the "category label" stimuli (such as "improve parking" for the task of "how can your university be improved?") demonstrated to enhance idea production in previous studies of group and individual brainstorming (Dugosh et al., 2000; Nijstad & Stroebe, 2006). VIBRANT's built in strategy for selecting a next focus was designed to balance breadth and depth of brainstorming across the idea hierarchy while maintaining the coherence of the conversation. This design is motivated by prior findings that brainstorming is more efficient when successive ideas are clustered so that semantically related ideas are contributed in close proximity, and transitions between general idea categories are relatively rare (Nijstad & Stroebe, 2006).

For the IS condition, VIBRANT offered feedback in response to each contribution of the student. For the PS condition, in order to give students time to react to each other's contributions before viewing automatically generated feedback, the system collected and evaluated the two students' contributions during a fixed period of time, and then gave feedback based on the accumulated text. This adjustment of the parameter, length of time for collecting dialogues, may be viewed as adjusting how interruptive the computer agent is. In this study, the parameter was set to 30 seconds, which was observed during a pilot experiment to allow students enough time to interact with one another. No feedback from the system was offered to students in the two no support conditions. Thus, in contrast to the two support conditions just described, for the IN condition, a simple computer agent did nothing but simply recorded students' contributions. Students were simply instructed to use the IM program as a text input buffer. A similar simple agent was used in the PN condition where pairs of students brainstormed together on the IM platform but received no system support.

Participants

The study was conducted in a computer classroom of a public high school located in central Taiwan. Four sessions were scheduled in the same day, two in the morning and two in the afternoon. In each session, the computer classroom accommodated at most 16 students. Every student worked at a computer assigned to him or her. Participating students were allowed to choose the session they attended, and were randomly assigned to experimental conditions within that session. For experimental conditions PN and PS, students were paired into dyads randomly. The version of the MSN based software used as our experimental infrastructure was configured so that in the pair conditions, the other student assigned to the same dyad a student appeared in the "buddy list" of that student. Additionally, in the support conditions, the computer agent that provides feedback also appeared in the "buddy list". Thus, when the students would launch the application during the experimental manipulation, their MSN based client would be configured to support a conversation between all of the relevant parties. Altogether, there were 7 students in the IN condition, 7 students in IS, 14 students in PN (i.e., 7 pairs), and 14 students in PS (i.e., 7 pairs). During the study, all students were blind to the experimental design, and unaware of the existence of other conditions.

Experimental Procedure

The experimental procedure can be divided into five phases, namely (1) background readings, (2) pretest, (3) brainstorming 1, (4) brainstorming 2, and (5) the post test. The experimental manipulation took place during phase (3), which is the first brainstorming phase. The purpose of the second brainstorming phase is to test whether the experimental manipulation from phase 3 has an effect on brainstorming behavior that can be detected within a new brainstorming task. While prior work has evaluated the effect of collaborative idea generation on a subsequent individual idea generation stage where the idea generation task was the same, to the best of our knowledge this is the first evaluation in an experimental study of the effect of collaborative idea generation on a subsequent different idea generation task. We strictly controlled for time in all phases.

Phase 1. Background Reading (10 minutes)

During phase 1, the students read a 3 page packet of background reading materials on the climate, geology, and development of Taiwan as well as some information about natural disasters but no specific information about debris flow hazards. This packet was compiled by domain experts working in a science education center at National Taiwan Normal University. The readings were designed to offer students a wide range of background material related to the topics contained within the idea hierarchy discussed above, however it did not contain the direct answers to any questions on the test nor did it directly express the ideas students were required to contribute in the brainstorming task. The reading material itself does not explicitly introduce the factors underlying DFH occurrences. The purpose of the reading materials was to prepare student for the brainstorming task. Students in all conditions were instructed to read the material for 10 minutes, and to learn as much as possible from the material. The readings were given to students prior to the pretest so that any learning measured by pre to post-test gains can be attributed to the brainstorming task and not to the readings alone. At the end of the 10 minutes, students were asked to turn the reading materials over and not look at them. Lab attendants ensured that students followed the instructions.

Phase 2. Pre-brainstorming Test (15 minutes)

In phase 2, students took an on-line pretest assessing their conceptual knowledge and reasoning about debris flow hazards.

Phase 3. Brainstorming Activity 1 (30 minutes)

After the pretest, the students participated in the first brainstorming phase, which is where the experimental manipulation took place. Students were instructed to launch the MSN program and to start working on the DFH brainstorming task. Specific instructions for the task appeared as the first prompt in the MSN messenger window. Students were given a scenario about a specific debris flow hazard and then asked to generate as many thoughts as possible in answer to the question, "*what are the possible factors that may cause a debris flow hazard to happen?*" During this activity, students were invited to use the reading materials from Phase 1 as a resource. The duration of the brainstorming session was limited to 30 minutes.

Phase 4. Brainstorming Activity 2 (10 minutes)

Upon the completion of the brainstorming task, students regardless of experimental condition were then instructed to do individual brainstorming on a second brainstorming task. In this idea generation task, students were requested to offer preventive solutions for DFH. The prompt for this solution-finding brainstorming activity was "*what facilities or solutions may prevent a debris flow hazard from happening?*" No system support, reading material or peer interaction was provided when doing this transfer task. The purpose of this task was to assess whether the impact of the experimental manipulation had a lasting effect beyond the duration of the manipulation.

Phase 5. Post-brainstorming Test (15 minutes)

Finally, students took an on-line post-test identical to the one used as a pretest again in order to assess the influence of the experimental manipulation on learning outcomes. The time allowed for doing the test is also the same to the pretest phase (for 15 minutes).

Measurement

Three outcome measures were used and analyzed in this study, including pre to post-test learning gains, productivity during the initial idea generation task during the experimental manipulation, and productivity in a subsequent idea generation task.

We use a 26-item domain test for assessing students' concept comprehension on the DFH topic. The test itself can conceptually be further decomposed into two parts, factual knowledge recall questions (11 items) and more reasoning-oriented questions (15 items). The test served as the indicator of students' learning status at the pre-test and post-test phases. The test was designed by science education researchers for high school students and has been used in previous science education studies (Chang et al., in press). The validity and reliability of this instrument were discussed and established in prior studies (Chang et al., in press).

We examined the productivity of idea generation in the first brainstorming activity by using two counting methods: number of unique ideas contributed by each student and total number of unique ideas produced by groups as a whole. The first task performance measure was the number of unique ideas generated by each individual student. Students' brainstorming contributions are coded and classified to one of the 19 ideas modeled in the aforementioned idea hierarchy. Duplicate ideas are ignored in this analysis. For students who brainstormed with peers in the PN and PS conditions, we only counted an idea as a unique idea that student contributed if that student was the one who mentioned it first. The second performance measure we looked at is group-based idea production which is standard to studies of group idea generation in the literature (Diehl & Storebe, 1987). Unlike the first measure, here we looked at the output of brainstorming groups as a whole rather than that of individual group members. For students in the two individual sessions without a human peer (i.e., IS and IN), for a fair comparison, we formed 7 "nominal" dyads for IN and 7 for IS in a posthoc manner by randomly selecting two individuals from the same experimental condition (either IS or IN). Ideas generated by group members of nominal dyads were pooled for the comparison with real groups.

For the transfer task, students were evaluated based on the number of unique ideas they were able to contribute during the allotted time. Only ideas that matched a list of valid ideas collected during previous studies using this task counted in the unique idea count.

Results

Four hypotheses proposed at the beginning were evaluated and examined in the following analyses based on measures of conceptual learning, performance in the main brainstorming activity, and performance of the subsequent idea generation task.

Data Coding

Logs of all IM behavior in all conditions were saved for analysis. Altogether we collected 28 logs, 7 in each condition. Note that in the pairs condition, there is only one log per pair rather. To derive appropriate quantitative measures of idea generation for analyses, including task performance (number of unique ideas in the main idea generation task) and transfer performance (number of unique ideas the solution-finding transfer task), data collected in the main brainstorming phase (i.e., phase 3) and the transfer task phase (i.e., phase 4) have been coded.

For the main idea generation task, student IM conversation logs were first segmented into idea units, since during IM conversations, students may contribute more than one idea per turn. The inter-rater reliability between two independent coders over 10% of the data for sentence segmentation was satisfactory (Kappa= .7). Each unit contribution was then classified into one of the 19 domain concepts in the aforementioned idea hierarchy. If there was no feasible label for a particular contribution, the label of "other" was given. The inter-rater reliability for the concept coding over 10% of the data was also sufficiently high (Kappa=.84). As described previously, the number of unique ideas generated by each individual and the transformed efficiency measure (number of unique ideas/number of total unit sentences) were both computed from this coding. For the second brainstorming task, students' responses to were coded according to a coding scheme developed by domain experts based on prior studies. The categories in that coding scheme represent 15 valuable ideas. The inter-rater reliability of this coding of two independent coders over 10% of the data was Kappa=.74, which is satisfactory.

In order to gain insights about the social process of idea generation, the conversation logs were also coded on the social dimension of knowledge communication. A coding scheme consisting of 11 classes was developed. There are six valuable classes in the coding scheme which include *elaboration* (i.e., idea justification or explanation), *comment*, *positive evaluation*, *negative evaluation*, *question* (i.e., seeking for explanations), and *suggestion*. These valuable classes are considered as indicators that group members actively engaged in exchanging on-task information, arguing with each other, and co-constructing knowledge collaboratively. We also identified other four social codes which can be roughly characterized as off-task social interactions, including *encouragement*, *greeting*, *acknowledgement,* and *meaningless utterance*. Finally, for unit contributions which are solely idea instances carrying no social mode, we coded them as *idea*. The inter-rater reliability was acceptable (Kappa=.75).

Hypothesis 1: Differential Effect of Social Interaction on Idea Generation and Conceptual Learning

The prediction of hypothesis 1 consists of two parts. The first part predicts the presence of productivity loss in brainstorming groups, and therefore students who worked in pairs should be less productive in idea generation. The second part predicts that social interaction may promote conceptual learning. Thus, it is expected that students in the Pairs conditions would gain more knowledge as measured by the domain test.

Hypothesis 1-a: Productivity Loss in Pairs

Because production blocking is a well-known explanation for productivity loss in group brainstorming (Diehl & Stroebe, 1987), which may effect both idea production and learning, we began our analysis by investigating whether there was evidence of significant production blocking (i.e., having fewer chances to contribute ideas due to turn-taking) in our data either from the presence of a peer or from the involvement of a computer agent in the conversation, but we did not find evidence of this. We first computed an ANOVA with the two independent factors from our experimental manipulation as the independent variables and total number of student contributions (i.e., regardless whether they contain ideas or not) as the dependent variable. The ANOVA did not show a significant effect of the Individual/Pair factor, and in fact the trend was for students in the pairs condition to make more conversational contributions than students in the individual conditions. Similarly, not only did we not find evidence of production blocking due to the presence of a computer agent in the conversation, we found a marginal main effect in favor of System Support associated with the System-support/No-support factor, $F(1, 38)=3.62$, $p<.1$, with a medium effect size $f=.26$ (Cohen's $f=.25$-$.40$, or equivalently, Cohen's $d= .50$-$.80$) (pp. 286-287, Cohen, 1988) (System Support- Mean: 30.43, S.D.: 15.01; No Support- Mean: 19.95, S.D.: 10.24), demonstrating that the trend was in the opposite direction of what would be predicted if there were production blocking based on this very rough measure of production blocking. Thus, we do not find evidence that the presence of either a human or computer partner for brainstorming reduces the opportunity for students to contribute to the conversation.

Although there was no evidence of production blocking, in the analyses we still find evidence of productivity loss from the Pairs conditions when we use unique ideas matching one of the 19 ideas selected by science educators for this task. The primary ANOVA model was set up by using the first performance measure that we have mentioned in the following way:

(A-1) D.V.: Number of Unique Ideas by Each Student, I.V.: Individual/Pairs, System-Support/No-Support

A significant main effect for Individual/Pair in favor of *individual brainstorming* was found, $F(1,38)=70.94$, $p<.001$, Cohen's $f=1.37$ is very large (Individual- Mean: 9.57, S.D.: 1.91; Pair- Mean: 4.61, S.D.: 1.73). With respect to the other independent factor, the presence of adaptive feedback generated by VIBRANT seemed to have a trend benefiting the number of unique ideas but did not result in significant difference. No interaction effect was found. We also looked at the group-based production performance by using the second productivity measure, in which we formed nominal groups for experimental conditions IN and IS, and then pooled ideas generated by nominal group members statistically. By using the group-based measure, a significant main effect on the comparison of nominal groups versus interacting groups (i.e., real groups, PN and PS conditions) was found, $F(1, 24)= 20.7$, $p<.001$, $f= .93$, which is still large (Nominal Pair- Mean: 12.36, S.D.:1.55; Real Pair- Mean: 9.21, S.D.:2.12).

Hypothesis 1-b: Learning Outcomes in Pairs

In connection with conceptual learning, we first evaluated the general learning outcomes in terms of concept comprehension by computing a repeated measures ANOVA with time point (pre versus post test) as an independent factor. From this analysis we determined that there was a main effect of time point with no two-way or three-way interactions with our experimental manipulation. $F(1,76)= 9.35$, $p < .005$, Cohen's $f = .35$, which is a medium to large effect size (Pretest- Mean: 7.41, S.D.: 1.32; Posttest- Mean: 8.14, S.D.: 1.35). Thus, we conclude that students across conditions learned significantly from pretest to posttest in the brainstorming activity.

Then we examined the effect of our experimental manipulation on the magnitude of learning. We hypothesized that because of the benefits of collaborative learning interactions, we would see a learning benefit for collaborative idea generation even in the face of process losses with respect to productivity oriented outcome measures. We did find evidence of an increase in the number of instances of the types of conversational contributions we expected to be associated with learning in the pairs condition based on our analysis of the corpus, especially in the condition where the pair of students interacted with the VIBRANT agent. In particular, by counting the number of valuable social contributions that we have annotated (i.e., the six task-related social codes.), through an ANOVA analysis, it is determined that students who worked in pairs produced more valuable social interactions than students who worked individually, F(1, 38)=5.1, p<.05, a medium to large effect size f=.37 (Pair- Mean: 8.96, S.D.: 9.20; Individual- Mean: 3.36, S.D.: 4.45). There was no main effect of system support and no interaction effect. Table 1 further shows the average numbers of social contribution per category that occurred per session in each experimental condition. Note that number of ideas in this table refers to any idea contribution, whether it was unique or not, and whether it matched one of the 19 pre-specified ideas or not. From the top of the table, it appears that for the two Individual conditions, students narrowly focused on the core idea generation task. Very few extended explanations or other social interactions were ever uttered. Even in the PN condition the number of valuable social codes (e.g.., elaboration, comment, positive/negative evaluation, question and suggestion) is still low, and *not* significantly different from their occurrence in the Individual conditions. From the comparison between PN and PS, it is noteworthy that though our system feedback did not explicitly prompt students to engage in social interactions, such as elaborations, comment and evaluations etc., the current feedback seemed to indirectly trigger more intense social interaction within the pairs condition. Students in the PS condition have significantly more social contributions than those in other conditions especially in connection with several particular social codes, such as elaboration, comment and positive/negative evaluation that are associated with transactive collaborative discourse (Weinberger et al., 2005). The result can be viewed as the evidence that interaction with a collaboration support agent such as VIBRANT can lead to an increase in transactivity (Weinberger, 2003) in the ensuing collaborative discourse, however the impact was not great enough to lead to increased learning when comparing IS with PS.

Table 1. The mean and S.D. of various social contributions per student per session in each experimental condition. Superscripts indicate statistically different levels of occurrence.

	IN	IS	PN	PS
Idea	20.71 (4.96) ^{A}	21.00 (5.35) ^{A}	11.00 (4.10) ^{B}	17.36 (9.88) $^{A\,B}$
Elaboration*	1.14 (2.19) $^{A\,B}$	0 ^{B}	.64 (1.34) $^{A\,B}$	1.36 (1.28) ^{A}
Comment*	2.43 (3.60) $^{A\,B}$	1.29 (2.21) ^{B}	2.86 (3.68) ^{B}	6.71 (6.50) ^{A}
Positive Evaluation	0 ^{B}	1.86 (2.04) $^{A\,B}$	.57 (1.16) ^{B}	2.43 (2.53) ^{A}
Negative Evaluation	0 ^{B}	0 ^{B}	0 ^{B}	.57 (.76) ^{A}
Question	0	0	1.07 (3.25)	.79 (1.37)
Suggestion	0	0	.29 (.61)	.64 (1.45)
Acknowledgement	0	0	.71(1.64)	1.07 (1.54)
Greeting	0	0	0	.57 (1.16)
Encouragement	0	0	.14 (.53)	.07 (.27)
Meaningless	0 ^{B}	0 ^{B}	.5 (1.09) $^{A\,B}$	2.00 (2.48) ^{A}

*Student's t test, others: Tukey ; Values not labeled with the same letter are significantly different

We then evaluated whether the increase in occurrence of valuable social contributions in the Pairs condition were associated with increased learning as measured by pre to post test gains. We did this using an ANCOVA analysis configured as below:

(A-2) D.V.: Total posttest score, I.V.: Individual/Pairs, System-Support/No-Support, Covariate: Pretest score

There was a significant main effect of System Support, F(1, 38)=4.57, p<.05, Cohen's f = .35, which is a medium to large effect. Students in the system-supported conditions achieved significantly higher *adjusted posttest scores* (System Support- Mean: 8.61, Std. Err: .20; No Support- Mean: 8.02, Std. Err: .21). A significant main effect was also found on the factor Individual versus Pair F(1,38)=12.17, p=<.01, effect size Cohen's f=.84, which is a large effect. Students who brainstormed individually without a peer learned significantly better (Individual- Mean: 8.85, Std. Err: .25; No Support- Mean: 7.78, Std. Err: .17). No statistical interaction effect was found between the two independent variables. The ranking of adjusted posttest scores for the four experimental conditions is: IS (Mean: 9.05, Std. Err: .34) > IN (Mean: 8.66, Std. Err: .37) > PS (Mean: 8.12, Std. Err: .24) > PN (Mean: 7.43, Std. Err: .24). Students learned most in the IS condition, in which VIBRANT adaptive feedback was available, while no peer was present. However, only the difference between the two extreme conditions (IS and PN) is significant based on a Bonferroni post-hoc analysis. Students who brainstormed with the VIBRANT agent learned significantly more than students who brainstormed with a peer and no system support.

Though the phenomenon of productivity loss was observed consistent with hypothesis 1, in connection with conceptual learning, a pattern in opposition to hypothesis 1's prediction was obtained. Students did not learn conceptual knowledge better due to social interaction, and in fact, students in the Pairs conditions learned significantly less. A further exploration on the relation between idea production and learning outcomes revealed a correlation between the two measures. By classifying students into two groups according to a median split of their numbers of unique ideas generated, and using the domain pre-test as the covariate, it was found students with higher numbers of unique ideas scored significantly higher on the domain post-test, $F(1, 39)=9.03$, $p<.01$, a large effect size Cohen's $f=.48$. Students with more ideas scored better in the domain test (More productive brainstormer- Mean: 8.66, Std. Err: .23; Less productive brainstormer- Mean: 7.75, Std. Err: .20).

Hypothesis 2: Effect of Categorical Cognitive Stimuli

Hypothesis 2 predicts that students who brainstormed alone with the VIBRANT agent (i.e., the IS condition) would be more productive than students working purely in pairs (i.e., the PN condition). The comparison of IS and PN can be viewed as comparing the how different types of stimuli affect the cognitive process of idea generation. Both conditions had only one source of stimulation, either carefully designed stimuli from a computer agent or naturally occurring stimuli from a human peer. A Bonferroni post-hoc test on a previously introduced ANOVA model (A-1) showed that there was a significant difference between IS and PN on their productivity during brainstorming 1 (IS- Mean: 10.14, S.D.: 1.95; PN- Mean: 4.50, S.D: 1.91). While interaction with a human peer leads to a significant decrease in idea production, we do not see this effect resulting from interaction with the VIBRANT agent, and in fact the trend is in the opposite direction. This finding supports hypothesis 2.

Hypothesis 3: Adaptive feedback as Learning Support

Hypothesis 3 predicts that students would learn domain concepts from the VIBRANT's adaptive feedback intended as cognitive stimuli for brainstorming. From the ANCOVA model (A-2) introduced previously, it was determined that students learned significantly better when adaptive feedback was available. No interaction with other variables was found. Hypothesis 3 was supported by this result.

Hypothesis 4: Effect of Social Interaction on Subsequent Idea Generation

We hypothesized that students who worked in pairs in the main brainstorming task would be more effective at a subsequent related but different idea generation task. We first examined the relation between performance in the subsequent idea generation task and other measures. The number of unique ideas was used as the measure for this transfer task. No significant relation was found between measures of the transfer task and the main task. Nevertheless, by categorizing students into two groups, High/Low reasoning ability in the domain, according to a median split on their performance on the reasoning-oriented part of the domain test, students with high reasoning ability in the domain were determined to be more capable in the second idea generation task, $F(1, 40)=4.28$, $p<.05$, a medium to large effect size Cohen's $f=.33$ (High reasoning- Mean: 5.75, S.D.: 1.89; Low reasoning: Mean: 4.77, S.D.: 1.11).

A two way ANOVA was conducted by using the number of unique solutions as the dependent variable, experimental manipulations as independent variables, and the aforementioned label on High/Low domain reasoning ability was added into the ANOVA model to account for variance related to that factor. A significant main effect was found for the Individual/Pair factor, $F(1, 37)=7.67$, $p<.01$, a large effect size $f=.46$. The result was in favor of *working in pairs* (Pair- Mean: 5.54, S.D.: 1.58; Individual- Mean: 4.64, S.D.: 1.50). Also, a significant interaction effect was detected between our two experimentally manipulated factors, $F(1, 37)=5.57$, $p<.05$, $f=.39$, which is close to a large effect size. PS was found to be the best condition in the transfer task (Mean: 5.79, SD: 1.72), while IS was the worst (Mean: 4.00, SD: 1.41). A post-hoc pair-wise Bonferroni analysis showed that PS and PN both had significantly better performance than IS in the transfer task.

Hypothesis 4 was therefore supported. Students in the Pairs conditions preformed better in a subsequent idea generation session, in which a related but different task became the target and no external support was available.

Conclusions and Current Directions

We have presented the results of an experimental study investigating both the long term and short term effects of brainstorming in pairs versus brainstorming individually in an inquiry learning context. Our finding is that brainstorming tasks can be beneficial for student learning. Furthermore, because of a significant correlation between brainstorming productivity and pre to post test learning in our data, the results support the view that learning from brainstorming comes from the constructive process of idea generation. Beyond that, the condition favored by the results depends upon what outcome measure is valued above the others. For example, students in the pairs condition were less productive and learned less during the initial brainstorming task. On the other hand, the students who brainstormed in pairs during the first session performed better on the second brainstorming task. Furthermore, although brainstorming support had a positive effect on learning both in the individual and pairs conditions, it did not have a significant positive effect on productivity during the initial brainstorming session. Nevertheless, since high reasoning ability students performed better on the second task, we see the learning gains especially related to the reasoning portion of the pre/post test that resulted from the feedback as providing a potential lasting positive effect on future brainstorming. If the relationship between idea generation and learning can be verified to be a causal one, a brainstorming agent that better supports productivity may also better support learning. Since students in the pair conditions were observed to have many repetitions and paraphrases of the same ideas, one potential future agent design might be one that encourages partners to explore different parts of the idea space to avoid producing redundant ideas, and potentially to avoid process losses due to cognitive interference (c.f., Nijstad & Stroebe, 2006).

This work was funded in part by the National Science Council (NSC), Republic of China grant number NSC 94-2511-S-003-028 and National Science Foundation grant number SBE0354420.

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Fading Scripts in Computer-Supported Collaborative Learning: The Role of Distributed Monitoring

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Abstract: Computer-based collaboration scripts constitute a form of distributed control and disburden the learners from the regulation of their performance, which they must internalize in order to acquire cognitive skills such as argumentation. Accordingly, without further support, e. g. by distributed monitoring by a learning partner, fading may be ineffective. Therefore we examined whether fading fosters skill acquisition only in combination with collaborative support. In an experimental study with the factors fading and distributed monitoring, learners were supported in an online discussion forum by a collaboration script for the production of counterarguments. Results show that fading fostered the acquisition of declarative knowledge about argumentation only in combination with distributed monitoring, whereas with regard to procedural knowledge about argumentation there were no differences. These results indicate that fading supported by aspects of computer-supported collaboration can increase the effectiveness of fading for skill acquisition even in early stages of skill acquisition.

Collaboration Scripts as Process-related support in CSCL to foster the acquisition of cognitive skills

Forms of process-related support have been developed for computer-supported collaborative learning to induce productive collaborative activities, such as the resolution of socio-cognitive conflict, transactive discussions or well-grounded argumentation, and thereby increase the acquisition of knowledge and skills (King, in press). One specific type of process-related support are collaboration scripts (Kollar, Fischer & Hesse, in press; cf. also Kobbe et al., subm.): Collaboration scripts are directed towards specific *goals* for learning in the collaborative situation, specify *activities* that are functional for these goals, *sequence* them and assign them to different *roles*. Furthermore, collaboration scripts can be *represented* differently. These representations may be "internal" as knowledge of the persons involved in the collaboration (scripts as format for the representation of knowledge, cf. Schank & Abelson, 1977), or "external", e. g. on prompt cards or as prompts in the graphical user interface of a computer-supported learning environment. In the case of external representation collaboration scripts constitute a form of distributed control (cf. Perkins, 1993) of collaborative activities (Carmien, Fischer, Fischer, & Kollar, in press): The externally represented script contains the information necessary to coordinate the collaborative activities of the participants. To conduct these activities, however, the participants have to rely on their own knowledge on how to perform the activities induced.

Often, collaboration scripts are not primarily aimed at fostering the acquisition of domain-specific knowledge, but at the same time also the acquisition of skilled performance of the collaborative activities shaped by the script. From the perspective of theories of cognitive skill acquisition, the acquisition of a cognitive skill often departs from a process of problem-solving by using *declarative knowledge* that is then gradually transformed into *procedural knowledge* after repeated performance (VanLehn, 1989). Of this knowledge, one type is required to construct a hierarchy of sub-goals necessary to solve the problem at hand, whereas a second type of knowledge is related to how to accomplish the single sub-goals (cf. Anderson, 1987, p. 198). While the knowledge necessary for the accomplishment of the sub-goals is presupposed by computer-supported scripts that specify activities that are supposed to be mastered by the learners, the second type often is represented in the elements of the interface used to implement the script (e. g. text boxes, prompts, graphical representations of a procedure) to a large extent and needs to be internalized by the learners to acquire the strategy contained in the script. To be sure, also aspects of declarative domain-specific knowledge may be represented in scaffolds provided by the interface, but these may be less likely to negatively affect the acquisition of cognitive skills, as we assume against this theoretical background.

In the current context, we investigate a skill that is central to CSCL research: the skill of argumentation. In this study, we particularly focus on one specific aspect of argumentative skills, i. e. the skill to contribute counterarguments. In an online-discussion, counterarguments can be contrived by means of a strategy that comprises the following steps: Identifying a claim in a contribution of a learning partner, identifying a corresponding argument, determining the type of the claim, determining the type of the argument, checking the conditions required for the argument to be relevant for the claim (cf. Naess, 1966) and formulating the answer. The learners are supposed to transform this sequence into a cognitive skill.

Types of claims that frequently occur in problem-based learning in the domain of psychology are, for example, diagnoses and recommendations of interventions. What can be regarded as a good argument for or against a specific claim depends on the type of the claim at issue (cf. Toulmin, 1958). Claim-specific knowledge about argument schemata is used during skill execution to adapt the following sub-goals in a content-specific manner depending on the previous processing: For example, after determining the type of a claim one can set the sub-goal to check whether the argument belongs to one of the argument types that fit the claim type.

Fading of collaboration scripts – can the learning partner help?

It is regarded as important to reduce external support gradually (fading) in order to leave room for self-directed performance of the skills to be acquired (e. g. Pea, 2004; Puntambekar & Hübscher, 2005). The idea of fading originated from behavioural approaches and has been research intensely in the area of learning disabilities (Demchak, 1990). However, it has also been taken up by cognitively-oriented researchers: A cognitive line of argument for the necessity of fading for learning claims that also the retrieval of knowledge has to be practiced and therefore the informational content of prompts needs to be reduced in order to provide the learners with opportunities to practice the retrieval of knowledge for the regulation of their behaviour (Riley, 1995). In the context of situated approaches, fading is considered in close relationship with scaffolding: Learners are supported in dealing with tasks that would be too difficult to them without support. By gradually reducing the support, however, they build the necessary competencies (Collins, Brown & Newman, 1989). In the area of the acquisition of cognitive skills, fading is applied successfully to learning from worked examples (Renkl & Atkinson, 2003). In this context, in a series of analogously structured worked examples, more and more steps of the problem-solving process are left out (e. g. Atkinson, Renkl & Merrill, 2003). A further example from the field of cognitive skills is Leutner's (2000) „double-fading support“ approach. Here fading is regarded as an opportunity to learn the "management of mistakes“ and takes place on two levels: On the one hand, the degree of detail in the instructions for the use of a software application is gradually decreased, on the other hand, the degree of simplification of the application by the blocking of functions is reduced. Also in this context fading has proven effective for learning. These studies provide some preliminary support for the idea that fading may also foster the acquisition of cognitive skills by means of scripts.

However, approaches to cognitive skill acquisition assume that the acquisition of procedural knowledge is based mainly on knowledge application during problem-solving (e. g. Anderson, 1982). Furthermore we assume that the type of knowledge responsible for the control of the execution of the skill is provided by the script, which delivers the sub-goals to the learner in a "ready-made" fashion, and is accordingly taken over by it to a large extent, Therefore, one would have to expect that the learners will not internalize control knowledge *before* the fading starts and fail to control the performance of the skill to be acquired *after* the fading starts. This may even hold for declarative knowledge underlying the skill, which is assumed to play an important role in early phases of skill acquisition (Anderson, 1982).

Therefore the question arises how learners can be supported early in the learning process to take over the control of their performance. According to the approaches to skill acquisition outlined above, the kind of knowledge required for this would most likely be acquired if learners were stimulated to use and *apply* this knowledge themselves, i. e. to derive sub-goals themselves independently of the prompts in the script already while the complete script is still available.

Interestingly, the role of collaboration in fading and in skill acquisition has rarely been explored. Ideally, computer-supported collaboration may play a crucial role in fading. One obvious possibility to encourage learners to derive sub-goals could be monitoring by a learning partner in the sense of distributed metacognition (King, 1998). Being monitored in one's performance might facilitate to think of the steps to be performed already during the formulation of their contributions in order to avoid negative feedback from their learning partners. An effect of this kind has already been demonstrated for feedback by teaching persons: In a study by Vollmeyer and Rheinberg (2005), the mere expectation of feedback increased the quality of the strategies applied. Moreover, the feedback on one's own performance is likely to improve performance significantly (Kluger & DeNisi, 1996). In CSCL environments, there are several interesting possibilities to enhance this process of distributed monitoring. In particular, technology can support the monitoring partner to access and review specific information about the process of the collaborator's performance. For instance, specific information that makes transparent how a learner proceeded in contriving a critical reply, can be made available to the learning partner. Furthermore, the learning partner can be supported by elements in the interface to provide focused feedback on the learners' performance. In addition, monitoring can be supported by the technology through prompting and hinting with respect to the aspects of the performance that should be focused on.

It is the *goal of this study* to investigate, how fading of collaboration scripts affects the acquisition of a cognitive skill, and to what extent computer-supported collaboration – implemented in the form of distributed monitoring– would mediate these effects.

Research questions

The research questions of this study were the following:

(1) Do the fading of scripts and distributed monitoring interact with respect to the acquisition of declarative knowledge underlying a cognitive skill?

(2) Do the fading of scripts and distributed monitoring interact with respect to the acquisition of procedural knowledge underlying a cognitive skill?

It was expected that the acquisition of the both the declarative and the procedural knowledge underlying a skill is fostered by fading only in combination with distributed monitoring.

Method

Participants and design

The participants of the study were 120 students in courses in educational science and teacher preparation who attended a lecture with the title "introduction to educational psychology". They were randomly grouped in dyads who discussed on separated online discussion boards during the collaborative learning phase.

A 2x2 design with the factors fading and distributed monitoring was implemented (see table 1).

Table 1: Design of the study.

		Fading	
		No	Yes
Distributed monitoring	No	12 dyads	18 dyads
	Yes	13 dyads	17 dyads

Learning environment and material

The two learners in each group dealt with cases on the application of Weiner's attribution theory in a text-based online discussion board (described, e. g., in Weinberger, 2003). They were told that they were discussing analyses of these cases in groups of four and that two of the other learners had the task to write these analyses. The learners themselves were asked to write critical replies to each of theses analyses and could discuss online any questions that came up during this task. In fact, six case analyses that were developed on the basis of authentic material from earlier studies with at least two questionable claims in each were posted to the board under the names of the two would-be group members at fixed points in time. As a preparation for this cooperative learning session, the learners read a three-page text on Weiner's attribution theory and a four-page text on how to construct counterarguments in the critical replies.

The script supported the learners in the process of formulating counterarguments against the prepared case analyses by providing instructions on how to analyze the argumentation in the case analyses and to discover problematic assumptions. It was implemented in the interface (cf. figure 1), which contained three kinds of script-related information: sequence information, argument schemata and application support. In the upper left-hand corner, the case analysis to be criticized was displayed.

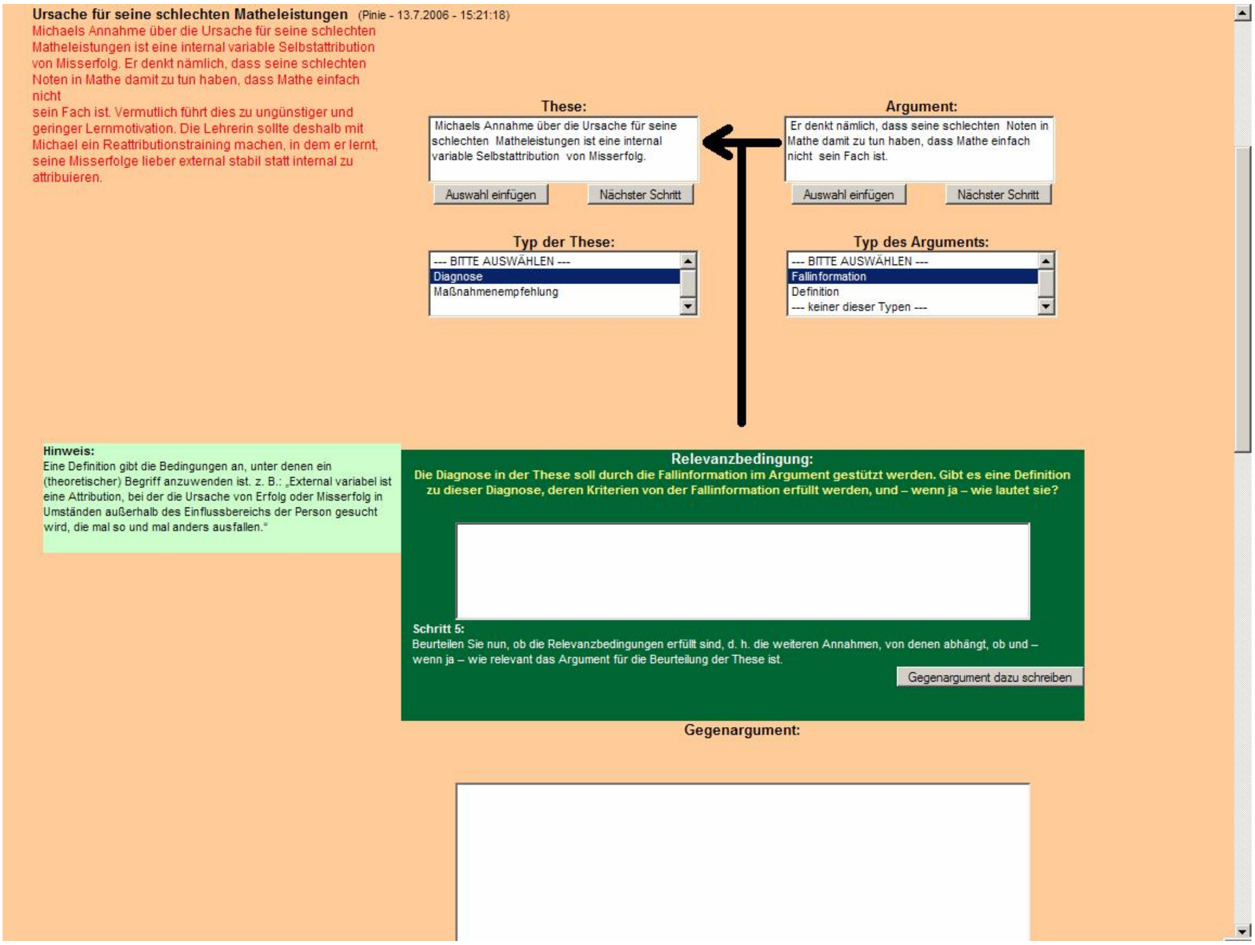

Figure 1. Implementation of the script in the interface of the online discussion board
Important terms:
"These" – claim, "Typ der These" – type of claim, "Typ des Arguments" – type of argument,
"Relevanzbedingung" – condition required for the argument to be relevant for the claim,
"Gegenargument" - counterargument

Sequence information described the process of analyzing the argumentation in the prepared case analysis and the construction of a critical reply to it. It specified the next step in the sequence already mentioned: Identifying a claim in a contribution of a learning partner, identifying a corresponding argument, determining the type of the claim, determining the type of the argument, checking the conditions required for the argument to be relevant for the claim, and formulating the answer. Sequence information was implemented in the interface as prompts that changed according to the state of the editing. These prompts were displayed in darkly coloured areas that highlighted the interface element in which the step should be performed, as shown in figure 1 for the step of checking the conditions required for the argument to be relevant for the claim

Argument schemata contained information on what types of argument are appropriate to support the identified type of claim and what conditions of relevance need to be fulfilled for an identified pair of argument and claim, which was crucial for the assessment of the argumentation in the case analysis. These schemata were implemented by means of selection fields for the type of the claim and the argument, which constitute the second row of boxes in figure1, as well as by a prompt for the assessment of the condition of relevance, displayed above the highlighted box for the assessment of the conditions required for the argument to be relevant for the claim in figure 1. The options in the field for the argument type was adapted according to the type of claim selected in the corresponding selection field, and so were the prompts for the assessment of the conditions of relevance according to the type of argument selected in the corresponding selection field. Accordingly, the specific content of script support branched depending on the selections made by the students on earlier steps.

Application support was provided by explanatory sentences for the terms used in the prompts and selection fields of the script as well as examples for the respective types of propositions (in accordance with the text on how to construct counterarguments in the critical replies). They were shown in the interface directly next to the respective control elements in lightly colourd text areas, as shown to the left of the box for the assessment of the conditions of relevance in figure 1.

At the bottom, the interface contained a textbox for editing the message, which was pre-composed based on selection and inputs made on earlier steps, as shown at the bottom of figure 1.

Operationalization of the independent variables

Fading.

As the specific content of the script support branches depending on the identified types of claim and argument, the elements of the script could be faded only after the learners could be expected to have selected the respective branch at least one time. Based on the design of the prepared case analyses, this could be expected after the posting of two contributions. For the branching of the specific content of the script support, unequivocal input was required. Accordingly, the interface elements corresponding to earlier steps of the script (e. g. the selection box for the classification of the claim) could not be faded befor the interface elements corresponding to the later steps of the script (especially the prompts aimed to support the checking of the conditions required for the argument to be relevant for the claim). The fading conforme dot the following schedules for the three kinds of information contained in the script:

The *application support*, i. e. the explanatory sentences designed to clarify the terms used in the prompts and selection fields of the script as well as examples for the respective types of propositions, disappeared completely after the second critical reply a learner posted with support of the script.

The *sequence information* prompts were faded in the following way: Ater the second critical reply posted with support of the script, two randomly chosen prompts for the next step were replaced by an unspecific prompt in each round. This unspecific prompt read as follows: "Please perform this step on your own." This entails, that after five critical replies posted with support of the script only this unspecific request was shown before each step.

The *argument schemata* were gradually reduced in a "backward" fashion after the second critical reply a learner posted with support of the script: On the third occasion, in which the learners constructed a critical reply a learner with support of the script, the specific question concerning the fulfilment of the condition of relevance (step 5) was replaced by an unspecific one. Starting with the fourth occasion, the selection field for the type of the argument did no longer contain any options, but the learners had to fill in the type of the argument themselves. Starting with the fifth critical reply constructed with support of the script, the selection field for the type of the claim did no longer contain any options, but the learners had to fill in the type of the claim themselves. After 70 minutes, finally the students were provided only with a simple text box for the formulation of their critical replies to the case analyses as customary in asynchronous discussion boards.

Distributed monitoring.

In the conditions with distributed monitoring, one of the learning partners had the task to provide the other learner with feedback for each of his or her critical replies to the case analyses, based on which the other learner was asked to revise his critical reply. During the formulation of the feedback, the learning partner was supported by the interface: By simply clicking on check boxes, feedback on the completeness of the six steps of the sequence for the construction of a counterargument, on the appropriateness of the identification of the types of claim and argument, and on the correctness of the answer to the question concerning the condition of relevance could be given. Furthermore there was the opportunity to add free text remarks. The distributed monitoring was continued after the start of the fading, i. e. the learners in these conditions were continuously provided with feedback on their procedure during the formulation of critical remarks.

Procedure

The collection of data was conducted in a series of sessions of three hours of length with 20 students each. These were distributed over two rooms in such a way that the learning partners who collaborated online sat in different rooms. After a short introduction into the purpose and procedure of the study, the participants filled in an online questionnaire (5 min) and read the texts on attribution theory (8 min). Then they were asked to write critical remarks against an attribution-theory-based analysis of a case from educational practice (10 min). After that, they read a text on how to construct counterarguments (12 min), which was printed on worksheets they could keep until the end of the learning phase. The collaborative learning phase started with an introduction and a demo video on how to use the learning environment (11 min). After a short break, the collaboration phase in the different experimental conditions followed (80 min). Finally, online post-tests for declarative and procedural knowledge about the construction of counterarguments as well as several control-measures were administered (40 min).

Dependent variables and instruments

The test for *declarative knowledge about the construction of counterarguments* asked for information given in the text on how to construct counterarguments and in the script (e. g. “Please enumerate the steps necessary to produce a counterargument.”). The free answers were coded according to mentions of the steps of the script (see above). The number of correctly remembered elements was used as the test score.

For the measurement of *procedural knowledge about the construction of counterarguments*, the learners were individually given a case analysis as during the collaborative learning phase and had the task to produce as many counterarguments against it as possible. Then, with respect to one of the counterarguments that were possible in the reply to the case analysis, they were asked for the results of the single cognitive operations regarded as necessary to contrive this counterargument (e. g. “Please identify the type of the following sentence: ‘Therefore, also in the forced course of bioinformatics she will not be motivated much.’”). These five items were intended to measure independent procedural knowledge components underlying the cognitive skill to produce counterarguments. Accordingly, it should not be possible to aggregate them to form one internally consistent scale. Rather, they should be included as distinct indicators of procedural knowledge about the construction of counterarguents in multivariate analyses.

Results

Research question 1: Interaction between fading and distributed monitoring with respect to the acquisition of declarative knowledge underlying a cognitive skill

The results for research question 1 concerning the interaction between fading and distributed monitoring with respect to the acquisition of declarative knowledge underlying a cognitive skill are presented in figure 2. The x-axis displays the two values of the fading factor, while the separate lines in the graph represent the distributed monitoring factor. On the y-axis, the score in the test for declarative knowledge about argumentation that asked for a description of the six steps involved in contriving a counterargument is displayed. Scores could range from zero to six. As we had hypothesized, the learners in the condition with both fading and distributed monitoring outperformed those in the group with fading only. Learners in the condition with fading only scored higher than the groups without fading and distributed monitoring and without fading and without distributed monitoring. The interaction between fading and distributed monitoring was significant ($F(3; 56) = 6.80$; $p < 0.01$; $\eta^2 = 0.267$). We further tested, whether the group with both fading and distributed monitoring demonstrated more declarative knowledge underlying the skill in the post-test than the three other groups. As the prerequisites for parametric tests were not fulfilled, a Mann-Whitney U test was applied. The difference between the learners in the combination condition and the learners in the other three conditions turned out to be significant ($U = 162.5$; $Z = -3.60$; $p < 0.001$).

Research question 2: Interaction between fading and distributed monitoring with respect to the acquisition of procedural knowledge underlying a cognitive skill

With respect to the procedural knowledge underlying a cognitive skill, the items measuring the occurrence of the single cognitive operations hypothesized to underlie the skill turned out to be independent from each other as intended. This means that, as intended, they did not constitute an internally consistent scale. Accordingly, they were used as separate indicators of procedural knowledge about argumentation in a multivariate analysis of variance. This analysis showed that there were no significant differences between any of the experimental conditions with respect to procedural knowledge about argumentation (Hotelling's Trace: $F(15; 149) = 0.388$; n. s.; $\eta^2 = 0.038$).

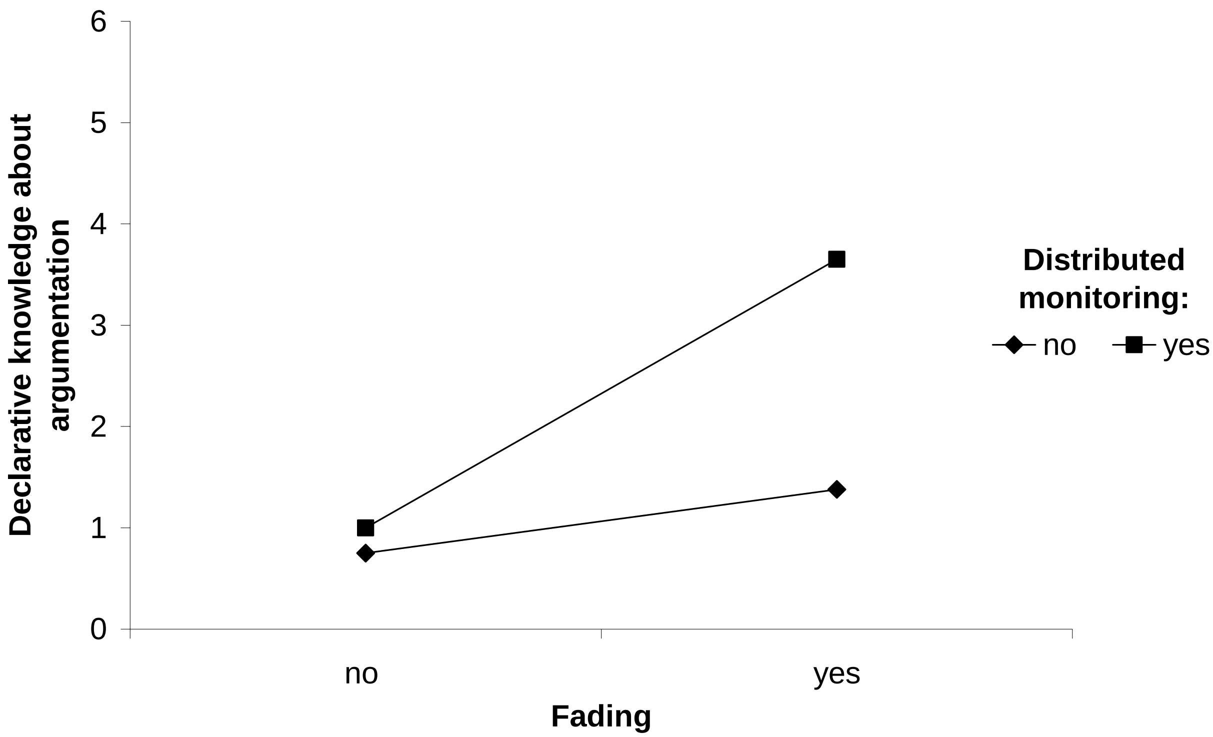

Figure 2: Declarative knowledge about argumentation in the four conditions

Discussion

With respect to the declarative knowledge underlying the cognitive skill of producing counterarguments, the results of this study confirmed our expectation that fading fosters learning only in combination with additional support such as distributed monitoring. Here computer-supported collaborative learning can add to the effectiveness of skill acquisition by coordinating the distribution of metacognitive aspects relevant for the internalization of knowledge embodied in a script. In particular, learners may receive support for taking over the control of their activities early in the learning process through collaboration that is facilitated by computer support.

With respect to the procedural knowledge underlying the cognitive skill, the corresponding hypothesis could not be confirmed. This negative finding could be possibly explained by the duration of the learning phase that might have not allowed most learners to enter the stage of skill acquisition in which declarative knowledge becomes proceduralized (Anderson, 1982). However, contrary to assumptions in the fading literature according to which fading should be most effective in later phases of skill acquisition (e. g. Renkl & Atkinson, 2003), our findings indicate that, under certain conditions, fading can bring advantages already in early stages of skill acquisition. These conditions include additional support for learners to take over the control of the performance of the skill to be acquired while the entire script is still available. Thereby it could be demonstrated that collaboration, in particular distributing aspects of metacognition such as monitoring among learners, can play an important role in helping learners to take over the self-regulation of their behaviour while support is gradually decreased. In some cases at least, merely reducing the support does not seem to be enough.

At least one further explanation for the negative result concerning procedural knowledge is possible: The students in the condition with both fading and distributed monitoring might have learned what to do and when to do it without having learned how and why to do it (cf. Brown, 1978; Veenman, Van Hout-Wolters & Afflerbach, 2006). This touches on two issues:

On the one hand, the script may have provided the learners with a strategy the components of which are not in the repertoire of the learners. So the failure of the students in the conditon with both fading and distributed monitoring to perform according to their declarative knowledge (i. e. demonstrate the corresponding procedural knowledge) may be a result of a lack of lower-level procedural knowledge, e. g. on how to check the conditions required for the argument to be relevant for the claim. Information about how to achieve this was provided in the introductory text on how to construct counterarguments as well as in the script, but it may not have been proceduralized in the course of the collaborative learning phase. Accordingly, higher-level procedural knowledge could not have been demonstrated in the post-test.

On the other hand, the learners may have failed to acknowledge the usefulness of the strategy contained in the script compared to their own prior argumentative competencies. For example, they may regard the skill to produce counterarguments as unimportant or the strategy itself as not helpful, believe that they will have resources similar to the script available when they will have to produce counterarguments in the future, or be rather confident in their own argumentative competencies. Each of these beliefs might lower the willingness to go beyond the acquisition of declarative knowledge underlying the skill to produce counterarguments.

Further analyses of the processes of learning and collaboration are required, both for providing a more detailed description of the learning processes that lead to differences in the acquisition of declarative knowledge and for deciding between the explanations offered for the absence of differences with respect to the acquisition of procedural knowledge. In order to establish whether failures in acquiring procedural knowledge are due to the unavailability of the operations that make up the strategy contained in the script, these analyses should focus on whether the learners' activities while they are guided by the script correspond to what was intended by the design of the script. In order to assess whether distributed monitoring functions in the way hypothesized, the learners' performance on steps that are no longer specifically prompted in the process of fading needs to be evaluated according to its correspondence with the strategy from the script. Furthermore, as studies show that these competencies develop over longer periods of time, (Kuhn, Shaw & Felton, 1997) the investigation of the acquisition of argumentative competencies supported by scripts and their fading should also be stretched in time to capture growth that occurs more slowly.

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Acknowledgments

The research reported in this paper was funded in the context of the Virtual Graduate School “Knowledge acquisition and knowledge exchange with new media” by the Deutsche Forschungsgemeinschaft (DFG).

Coordination Dynamics in CSCL based Chat Logs

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Abstract: This paper describes coordination dynamics in computer supported collaborative learning (CSCL) based chat logs. We developed a coding scheme for coordination processes containing 25 different coding categories, and used it to analyze chat data gathered in a semester-long education course. In general, we found a high level of coordination throughout the chat logs. The level of goal-related coordination (goal-related vs. not goal-related) varied extensively, depending on the specific task type. Based on an initial process analysis, a time pattern with regard to coordination levels was identified. We surmised that the amount of goal-related coordination and the point in time in which it occurs might play a role in coordination behavior. However, strong intra- and interindividual differences prevented us from detecting a distinct coordination pattern by numerical means over time. We conclude by proposing an extension of our analysis across media type and task type to detect coordination patterns relevant for collaborative learning.

Introduction

For collaboration to occur, coordination has to take place (Barron, 2000). Although coordination processes have been primarily analyzed in work teams, they also play an important role in learning groups, particularly in situations where groups both work together over longer stretches of time without being micromanaged, and work on tasks that require a division of labor. Malone and Crowston (1990) describe coordination as "the act of managing interdependencies between activities performed to achieve a goal" (p. 361) and identify different components of coordination: Two or more actors have to be involved in goal-directed activities. These activities are characterized by interdependencies. Such interdependencies can be common objects such as plans and diagrams, which are part of two or more activities, time as a constraining factor or the outcome of one activity that is required for another activity. Espinosa, Lerch and Kraut (2004) conclude that some interdependencies might be more important for successful performance than others. Groups have to be good at coordinating and managing the interdependencies that are crucial for the success of their particular task.

Most of the coordination literature has focused on face-to-face groups (Espinosa et al., 2004). However, collaboration in computer-supported groups occurs in a different setting and thus the nature of coordination must change. Another important factor for coordination processes is the task itself. Each task type goes along with specific coordination patterns. Arrow, McGrath and Berdahl (2000) stress the fact that behaviour of groups change over time Therefore, in order to illuminate coordination patterns in typical learning settings and their temporal patterns, we adopted an exploratory approach.

Educational Setting

This study examines the experience of seven participants in a postgraduate course in education during the course of a semester. The course was taught in a blended mode with 8 online and 5 face-to-face sessions. Participants' age ranges between 23 and 45 years, with an average of 31 (4 female, 3 male). Students formed two different groups with 3-4 members each. During the online sessions, groups collaborated through the content management system Plone®. Interaction between participants mostly took place in a synchronous chat environment developed within the CoCo Research Centre, University of Sydney (Ullman, Peters & Reimann, 2005), to be demonstrated at the conference. Students also used an asynchronous discussion board to some, albeit minor, extent.

Tasks were composed of the collaborative creation of Wiki pages, concept maps and joint group papers as well as the discussion and feedback to other group members' contributions to the online space. The tasks allowed for some degree of freedom as they typically asked for the collaborative production of an artifact, e.g. a concept map, but left coordination and collaboration means to the group to determine.

Coding Scheme for Coordination

Malone and Crowston's (1990) coordination theory guided us in the development of the coding scheme's categories. They distinguish four coordination processes: identification of goals, mapping of goals to activities, selection of actors/assignment of activities to actors and management of interdependencies. The category ‘interdependencies’ consists of five subcategories, such as addressing communication means, establishing simultaneity, negotiating shared resources and dealing with prerequisites. First codings revealed that in order to match existing chat log data better we added the category ‘establishing shared meaning’ (see Table 1).

An important part of coordination behavior is the response from the communication partner. In order to indicate closure of an action, we introduced two additional codes per category and subcategory, respectively: A plus (‘+’) indicates acceptance, elaboration, clarification or reassurance as a reaction to an initiation behavior. A minus (‘-‘) indicates rejection or disagreement. Closure was only coded if an utterance was a direct response to a coordination action.

Table 1: Overview of the coordination coding scheme.

(Sub-) Category	Definition	Examples
Goals (+/-)	• Identifying goals.	“Overall, what do we need to do?”
Activities (+/-)	• Mapping goals to activities.	“This is the to do list.”
Actors (+/-)	• Assigning activities to group members.	“I would like to see Ralph put the doc together as a Wiki.”
Interdependencies:	Management of interdependencies	
Communication means (+/-)	• Media usage for coordination purpose.	“Should we meet face-to-face to discuss this?”
Simultaneity (+/-)	• Synchronizing activities.	“Have you all read my notes?”
Shared resource (+/-)	• Allocating/discussing resources.	“Who is in our group for this task?”
Prerequisite (+/-)	• Ordering/demanding activities.	“Suggest other options.”
Shared meaning(+/-)	• Trying to establish a shared mental model.	“I am not sure, if I understand correctly.”
Non Coordination	• Entries not related to coordination.	

Semantic units served as units of analysis. Two raters used the scheme for initial coding. A first interrater agreement was estimated and the coding scheme underwent various revision cycles. The second rater coded about 50% of the existing data. The Kappa measure (κ=.77) for interrater reliability resulted in a satisfactory agreement.

Initial Results

The coding phase resulted in approximately 5800 coded events for 12 chat logs. We established a timeline for each of the two groups. The timeline for group A consists of 3500 events and the timeline for group B of 2300 events. This difference is due to the fact that group A felt more comfortable with the medium and chose to conduct additional voluntary chat sessions. Meanwhile, group B members decided to meet face-to-face.

With a few exceptions, the coordination process frequency per chat sessions was between 40% and 56%. Differences between the two groups can be noted. Group A showed an average of 42% coordination behavior in their chat logs and group B an average of 37%. Analysis of coordination frequency with regard to meaningful task units (a task unit combines all the chat logs regarding a particular task) revealed similar coordination patterns with only minor deviations across different task units. Even though both groups showed about the same amount of non-coordination behavior (59.7% group A and 62.5% for group B), group A showed more goal-related coordination (goal identification and goal mapping). About 0.9% of all utterances for group A were related to goal identification versus 0.4% for group B and 1.4% of all utterances for group A were related to goal mapping versus 0.3% for group B. An event log analysis, which plotted coded events along a timeline, revealed that group A performed goal-related coordination actions such as goal identification and goal mapping throughout the entire chat session whereas group B predominantly performed them during the second half of the sessions if at all. Although the overall amount of goal-related coordination differed between the two groups, they showed roughly the same pattern of goal-related coordination usage across the different task types (Figure 1).

In general, more initiations than closures were uttered (513 initiations versus 287 closures). Group A showed a convergent initiation–closure behavior pattern, more initiated actions were responded to by closures the longer the course lasted. Group B showed a divergent pattern, where an increase in initiation was accompanied by a decrease in closure. The more group members initiated the less they responded to their actions.

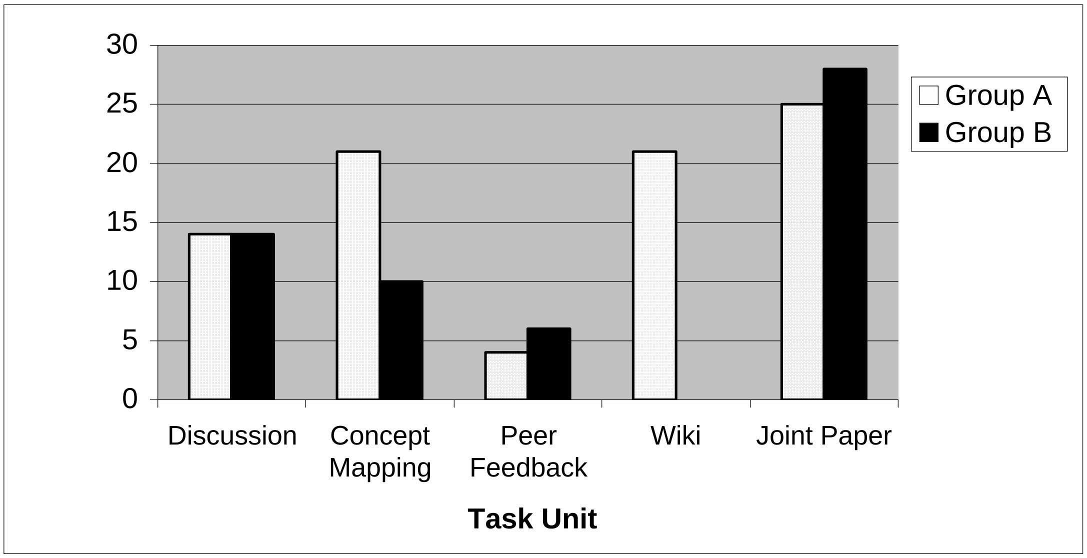

Figure 1. Goal-related coordination versus not goal-related coordination across task units.

Discussion

The two groups showed a high level of coordination throughout the chats, accounting for almost half of the utterances. The most striking pattern we discovered was in relation to the task type. Depending on the task type, groups showed a different percentage of goal-related coordination. Our analysis indicates an increased amount of goal-related coordination for one of the groups. Also they showed this behavior at an earlier point in time during their chat sessions. The amount of goal-related coordination as well as the time during the session might play a crucial role. At this point we were not able to establish a distinct pattern over time. This might be due to the fact that the two groups adjusted differently to the situation; while group A started conducting additional, voluntary chat sessions, group B decided to meet face-to-face in addition to the mandatory chat sessions.

Next Steps

As a next step, we would like to use the coding scheme on more groups, as well as perform more in-depth analysis of how coordination is established. Also it would be interesting to see how coordination behavior differs in groups with various levels of prior media experience.

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Interdisciplinarity in the CSCL Community – an Empirical Study

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Abstract. In previous work the CSCL community was analysed with respect to its scope, development, continuity and connectivity (Hoadley 2005, Kienle & Wessner 2005, Kienle & Wessner 2006). Main insights included a relatively low but stable continuity of individuals in the community, increasing international participation and increasing connectivity across different countries. Concerning the disciplines involved in CSCL and the disciplinary backgrounds of CSCL community members it was found that a variety of disciplines are represented in the community. A detailed analysis of the way these disciplines contribute to the progress of CSCL, the way members with different disciplinary backgrounds collaborate is still missing. In this paper we report an analysis of the CSCL community with respect to the disciplinary background of its members and the interrelation of various disciplines in CSCL. The analysis is based on a survey among members of the CSCL community actively involved in the CSCL 2007 conference (reviewers and authors of accepted contributions). The paper reports and discusses main results of this analysis with respect to disciplinary background of CSCL community members as well as links between the disciplines. In addition it provides insights into motives for interdisciplinary collaboration, beneficial and hindering factors. The results should help to sharpen our view of the CSCL community, contribute to a shared understanding about what CSCL (currently) is (and what is it not) and point out perspectives for future development of the CSCL community.

Keywords: CSCL community, community analysis, interdisciplinarity.

Introduction

The CSCL community has an ongoing task in developing a common theory that integrates the foundations of the relevant disciplines (Stahl, 2002; Puntambekar & Young, 2003). At CSCL conferences (e.g. 2003 in Bergen, Norway) lively discussions occur about the nature of the CSCL community and the identity of this field. In order to provide a more objective picture, the CSCL community was analysed with respect to its scope, development, continuity and connectivity (Hoadley 2005, Kienle & Wessner 2005, Kienle & Wessner 2006). Main insights included a stable continuity of individuals in the community, increasing international participation and increasing connectivity across different countries (data is available at www.cscl-community.org). Concerning the disciplines involved in CSCL and the disciplinary backgrounds of CSCL community members it was found that a variety of disciplines are represented in the community: While Hoadley (2005) found out that the majority of authors have a departmental affiliation in education, he counted authors with affiliations in nine more disciplines (plus 47 authors working in "other" disciplines). To cope also with authors working in "outlandish" departments, e.g. a psychologist working in a computer science department, and thus learn more about the collaboration between disciplines in the community on a daily work level, a more detailed analysis is needed. How do the disciplines contribute to the progress of CSCL? How do people with different disciplinary backgrounds collaborate in the field?

CSCL has been labelled as multidisciplinary (i.e. multiple disciplines work in a field side by side), pluridisciplinary (i.e. multidisciplinary plus comparision of methodologies and results), and interdisciplinary (i.e. multidisciplinary plus synthesis of methodologies and results) (see for example Klein 1990). While often these terms are used interchangeably, it is an important question for the CSCL community whether it is composed of relatively independent, monodisciplinary sub fields or whether there is true interdisciplinary collaboration. We do not elaborate further on the benefits of interdisciplinary work here. Hoadley (2005) argues that all drivers of interdisciplinary research apply to CSCL as its research topic is complex, not confined to one discipline, addresses a societal problem and is affected by new technologies. In their qualitative study Kienle and Wessner (2006) identified complementary competences and skills as one driving factor also for international collaboration in CSCL.

In this paper we want to provide answers to these questions about interdisciplinarity based on an analysis of the CSCL community focussing on disciplines and collaboration between members with different disciplinary backgrounds. Our hypotheses with respect to collaboration between disciplines are:

1. There is substantial interdisciplinary collaboration in the CSCL community as it can be seen from the research groups community members belong to and from the co-authorship of community artefacts.
2. There is a correlation between previous experience with interdisciplinary work and current interdisciplinary collaboration "behaviour" (i.e. if one has good experience with interdisciplinary collaboration chances are higher that he or she writes papers with interdisciplinary co-authorship).

In addition to evaluating these hypotheses empirically, we are interested in the motives, beneficial and hindering factors for interdisciplinary work in CSCL.

In the following section we describe the methods and data used in our analysis. Then we present and discuss the main results concerning our research questions and previous work. Finally, we conclude the paper with implications for the further development of the CSCL community.

Methods and Data

Our analysis is based on data gathered via an email survey among all reviewers and authors of accepted contributions of the CSCL 2007 conference.

The conference organisation of CSCL 2007 provided us with names, email addresses and affiliations for reviewers and contact authors. In addition we got titles and the lists of co-authors for all contributions (i.e. paper, poster etc.). Due to privacy reasons data on papers and authors was limited to papers which have been accepted for presentation at the conference and their authors. From the lists of reviewers and authors we generated two lists of CSCL community members: A first list ("only-reviewers") contains all reviewers who did not serve as contact authors of accepted contributions to CSCL 2007. A second list ("contact authors") contains all contact authors of accepted contributions also including contact authors who serve as reviewers.

For each group a questionnaire was designed in order to learn about interdisciplinary collaboration in general and wrt. accepted contributions to the CSCL 2007 conference. Due to our study design (i.e. to consider only accepted contributions) we could get the data only after all decisions about acceptance or rejection of all contributions had been made. After getting the data from the conference organisation we conducted an email survey among all reviewers and authors as specified above. Unfortunately, we had to set a strict deadline of one week in order to have enough time to analyse the results and prepare the final version of this conference paper. Our questionnaire is structured as follows:

For authors and reviewers:

- Discipline(s): In which disciplines is the person trained (i.e. has a degree) and which discipline does he or she consider as main discipline?
- Interdisciplinarity of the research group to which the person belongs: How many people work in that group (graduate students and higher)? Is it a monodisciplinary group (which discipline?) or are there colleagues with different disciplinary background (which ones?)?
- Previous interdisciplinary collaboration: How often did the person collaborate with colleagues with different disciplinary background in the past? How successful and satisfying was that collaboration?
- Main aspects in favour of interdisciplinary collaboration: free text
- Main aspects against interdisciplinary collaboration: free text

For authors additionally:

- Interdisciplinarity of the submitted paper:

- Concerning the list of authors: Is it a monodisciplinary team (which discipline?) or do co-authors have different disciplinary backgrounds (which ones?)? If co-authored are interdisciplinary: What was the reason for establishing this collaboration?
- Concerning the research methods applied in the paper: What research methods are used (if not clear form the registration/submission data)? To which disciplines are these methods assigned?
- Concerning the research topics tackled in the paper: What research topics are tackled (if not clear form the registration/submission data)? To which disciplines are these topics assigned?

In order to get a high acceptance for our survey in the community which should result in fast responses and a high response rate, we promissed that all results will be aggregated and presented anonymously.

From this data (registration/submission and survey) we planned to calculate the following distributions:

- Distribution of research topics
- Distribution of research methods
- Distribution of disciplines in the group of authors and of reviewers: e.g. computer science, psychology, information science etc. We will consider also people with a background in multiple disciplines, for example a person with a background in education and philosophy.
- Distribution of disciplines in the submissions
- Correlation between interdisciplinarity of papers and the nature of the authors' research group
- Correlation between interdisciplinarity of papers and previous experiences with interdisciplinary work

We will collect and cluster the responses concerning motives for interdisciplinary collaboration and beneficial and hindering factors for interdisciplinary work in CSCL.

In total there were 222 reviewers for CSCL 2007. 74 of these 222 reviewers were also contact authors of accepted contributions (papers, posters etc.) and received the author questionnaire. The remaining 148 reviewers received the reviewer questionnaire.
The total number of accepted contributions was 155. As some persons were contact authors for more than one contribution, there were 148 individuals who served as contact authors for these 155 contributions.

Response rates:

- We received feedback from 41 out of 148 reviewers who did not serve as contact authors for accepted contributions ("only-reviewers"; 28 %).
- From reviewers who also served as contact authors for accepted contributions we received feedback from 19 out of 74 (27 %).
- From contact authors who did not serve as reviewers we got feedback from 19 out of 69 (28 %).

As some authors were contact authors for more than one paper and also some non-contact authors (who got the questionnaire forwarded by the contact authors) responded, we got in total 47 author questionnaires. These questionnaires refer to 43 out of 155 accepted contributions (28 %).

Overall, a response rate of 27 – 28 % seems acceptable fo this email survey, especially as there was only 1 week time to fill out the questionnaire.

Results

This section presents the results of our analysis. First, this includes the distribution of research topics and methods, the distribution of disciplines, and the distribution of disciplines in the submissions. We present the correlation between interdisciplinarity of papers and the nature of the authors' research group as well as the correlation between interdisciplinarity of papers and previous experiences with interdisciplinary work.
Finally, we present the results concerning motives for interdisciplinary collaboration and hindering factors for interdisciplinary work in CSCL.

Research Topics and Methods

The questionnaire didn't provide a list of research topics or research methods to choose from. As a consequence the answers to these questions were very heterogenous wrt. granularity and terminology. Actually, they were so heterogenous that we did not try to calculate distributions of topics and methods for this paper. Nevertheless, we saw that in many cases the same topics and methods are assigned to different or multiple disciplines.

Disciplines and Main Disciplines

As for topics and methods we also did not provide a list of disciplines to choose from in the questionnaire. Thus again, the answers were heterogenous wrt. granularity and terminology. Table 1 lists the most frequently mentioned disciplines, table 2 the most frequently mentioned main disciplines for the subgroup "only-reviewers". Authors show similar distributions wrt. disciplines and main disciplines (not shown in this paper).

Table 1: Disciplines of reviewers.

Discipline	*Number of reviewers*
Computer Science/Computing	11
Psychology	10
Educational Science/Education	7
Educational Psychology	3
Electrical Engineering	3
Learning Sciences	3
Teaching	3
Biology	2
Curriculum & Instruction	2
E-Learning	2
Information Science	2
Sociology	2

In addition, each of the following disciplines were stated by one person:
Art History, Artificial Intelligence, Cardiorespiratory sciences, Cognitive Psychology, Cognitive Studies, CSCL, Cultural Studies, Curriculum and Methods of Teaching Arabic, Design, Digital librarianship, Economics, Educational Computing, Educational Measurement and Statistics, Educational Technology, Engineering, English & linguistics, English and American Literature, English Language and Literature, English Literature, Evaluation and Measurement (Education), Human-Computer Interaction, Informatics, Information Systems, Instructional Systems Technology, Knowledge Management, Library and Information Science, Linguistics, Media Arts, Music, Project Management, Research, Sciences, Social Science, Statistics, Telecommunications Engineering.

Note that these are 85 entries for a group of 41 persons, i.e. on average each person stated more than two disciplines she has an academic degree in.

Table 2: Main disciplines of reviewers.

Main discipline	*Number of reviewers*
Education	5
Learning Science	5
Computer Science	4
Educational Psychology	4
Psychology	4
Human Computer Interaction	3
Educational Sciences	2
Information Science	2
Linguistics	2

For each of the following disciplines exactly on person states these as main discipline:
Cognitive & Collaborative Technology, CSCL, Curriculum and Instruction, Database theory, Didactics
Educational Technology, E-Learning, Groupware Engineering, Language, Learning Theory, Library and Information Science, New Technologies, Science Education, Teaching, Telematics Engineering.

Correlation between interdisciplinarity of contributions and interdisciplinarity of the authors research group

Table 3: Correlation between interdisciplinarity of contributions and research team.

Contribution	*Research team*
Mono-disciplinary: 17	Mono-disciplinary: 4 Multi-disciplinary: 13
Multi-disciplinary: 24	Mono-disciplinary: 1 Multi-disciplinary: 23

Table 3 shows that in our sample (all author questionnaires that contain enough data about the interdisciplinarity of the contributions and of the research teams) only 5 of 41 teams are composed of reseherachers from only one discipline. 24 out of 41 contributions are made in interdisciplinary teams. And only in one case a multidisciplinary contribution is authored from a person working in a mono-disciplinary group. (This group consists of 2-5 members, i.e. it is relatively small.)
When we look at the main discipline of contributions authored individually or in mono-disciplinary teams we found out that 9 out of 17 mono-disciplinary papers originate from psychology or educational psychology.

Table 4: Correlation between interdisciplinarity of contributions and experience with interdisciplinary collaboration (collaboration behavior).

Contribution	*Collaboration behavior*
Mono-disciplinary: 17	Collaboration …on a daily basis 3 …regulalry 5 …sometimes 7 …never 2
Multi-disciplinary: 24	Collaboration …on a daily basis 10 …regulalry 11 …sometimes 3 …never 0

As we can see in table 4, behavior in inter-disciplinary seems to correlate with the interdisciplinarity of contributions. In table 5 we look at success and satisfaction of previous collaborations. Success and satisfaction with previous collaborations is considered higher from authors in multidisciplinary teams than in monodisciplinary teams.

Table 5: Correlation between interdisciplinarity of contributions and experience with interdisciplinary collaboration (success and satisfaction).

Contribution	*Collaboration success*	*Collaboration satisfaction*
Mono-disciplinary: 17	…quite successful 6 …mixed 8 ....quite unsuccessful 0 …no answer 3	…quite satisfying 8 …mixed 6 ....quite unsatisfying 0 …no answer 3
Multi-disciplinary: 22	…quite successful 13 …mixed 9 ....quite unsuccessful 0 …no answer 0	…quite satisfying 14 …mixed 8 ....quite unsatisfying 0 …no answer 0

Aspects in favor of interdisciplinary collaboration

Reviewers and authors stated the following arguments pro and con interdisciplinary collaboration (in our field) We clustered these aspects in the following way:

Interdisciplinary collaboration is natural and necessary for CSCL:

- Interdisciplinary collaboration is seen as natural and necessary as CSCL and the Learning Sciences are interdisciplinary fields, tackle complex problems which require interdisciplinarity.

Better outcomes:

- Interdisciplinary collaboration provides multiple perspectives, differents skills/strengths/opinions, different theoretical approaches and methodological frameworks, a broader knowledge base.
- Different views, different knowledge etc. can be combined, one learns more about others' perspectives and about the problem. The combination provides a mpore holistic view. People share problems and mental models.
- Methodological cross-fertilization
- Cross-fertilization of ideas
- Get a deeper understanding of other perspectives
- More useful outcomes
- Interdisciplinary collaboration leads to a focus on practice and provides common ground
- Reduce bias

Individual outcomes:

- Learn about other disciplines etc.
- Make connections to other disciplines
- Become more modest about your own field
- Refine and sharpen your methods and concepts

Political reasons:

- Increase awareness of learning sciences in science disiplines

Pragmatic reasons:

- provide setting for evaluation (classroom)
- provide hardware/equipment
- specialisation in a discipline ironically requires interdisciplinary collaboration.

Aspects challenging interdisciplinary collaboration

Differences lead to misunderstandings; require time/effort

- There are a lot of differences between disciplines, e.g. wrt. disciplinary culture, language. Researchers have different mental models, different criteria for evidence. These differences lead to confusion and misunderstandings. In order to overcome this there is a need for sharing and/or integration. This is costly and/or time-consuming. Time plays a role for the beginning of a int.coll. Also the maintanenace of an int. team requires high efforts. Dogmas and straight jackets of a discipline hinder integration.

Results don't justify effort

- Sometimes the results of int. coll. do not justify the effort/the time.
- Results are seen on a more theoretical level, not touchable. There is no increased understanding about the research topic.

Interdisciplinary collaboration requires good logistics (collaborators work in other buildings/campuses). It is not easy to balance the perspectives in one study.

It requires mutual perception and appreciation (programmer vs. real researcher; use sw/etc. from collaborators)

It requires certain individual skills

- Flexibility, openness for other approaches

Structures - Funding and Promotion:

- Int. coll. is demanded by university managers and politicians but existing structures hinder it: career, funding, promotion, tenure. There are little merits from int. coll.

Structures - Publication:

- It is difficult to find a venue for interdisciplinary research
- Least publishable unit vs. conceptually pulishable unit

Lack of interdisciplinary graduate level course work

Some problems simply don't require or benefit from interdisciplinary collaboration

Discussion

This section discusses the results presented in the previous section. Our hypotheses (see first section) were

1. There is substantial interdisciplinary collaboration in the CSCL community as it can be seen from the research groups community members belong to and from the co-authorship of community artefacts.
2. There is a correlation between previous experience with interdisciplinary work and current interdisciplinary collaboration "behaviour" (i.e. if one has good experience with interdisciplinary collaboration chances are higher that he or she writes papers with interdisciplinary co-authorship).

Wrt. the first hypothesis we have seen that more than half of the contributions (24 out of 41; in the sample of our study) were written in interdisciplinary teams. We have also seen that only 5 (out of 41) authors work in monodisciplinary teams. This demonstrates a substantial interdisciplinary collaboration in the CSCL community. Wrt. the second hypothesis we showed that experience with interdisciplinary collaboration correlates with the nature of author teams. Regular collaborators and people who experienced successful and satisfying collaborations before seem to be more open and willing to participate in new collaborations.

The analysis of the CSCL community members disciplines showed that people come from very different backgrounds and often have a background in more than one discipline (see also previous studies: Hoadley 2005, Kienle & Wessner 2006).

An interesting finding is that the majority of monodisciplinary contributions is in the field of psychology or educational psychology. This might indicate problems such as the ones mentioned in the factors hindering or challenging interdisciplinary collaboration, e.g. specific criteria for evidence, difficulties to find accepted publication outlets or low merits in psychology for interdisciplinary collaboration in view of funding or promotion.

As with many empirical studies, there are some limitations with our study which should be discussed here. It might be that the response to our questionnaires is biased because only a certain subset of the reviewers and authors responded to our questionnaire. For example, if only people respond who are interested in interdisciplinary collaboration (a number of respondends actually did express their interest in the study's results) then the CSCL community seems much more interdisciplinary than it really is. The actual response rate of 27 – 28% might also limit the significance of this study. Another problem originates from the international nature of the CSCL community: Disciplines have slightly different names and meanings in different regions or even exist only in some regions (as an example there is no program "Learning Sciences" at German universities). Thus, all quantitative statements should be handled with care.

Conclusions & Future Work

In this paper we presented an analysis of the CSCL community concerning the disciplines involved and the collaboration between disciplines. The analysis is based on latest data gathered in the context of the CSCL 2007 conference. Starting with a list of reviewers and contact authors an email survey has been conducted among all authors and reviewers for CSCL 2007.

The paper provided some evidence that there is substantial interdisciplinary collaboration in the CSCL community. This could be seen analysing the (inter-)disciplinarity of research groups and author teams in the CSCL community. We have also seen that an author's experience with interdisciplinary collaboration correlates with the interdisciplinarity of the CSCL 2007 conference contributions of that author.

CSCL researchers are convinced that CSCL in many or most cases requires interdisciplinary collaboration (see section on aspects in favor of interdisciplinary collaboration above). Thus, it is important to tackle the challenging aspects for interdisciplinary collaboration as mentioned above. Such actions cover multiple layers of the CSCL community. Some challenges can be addressed by each individual CSCL researcher, others require strategic actions on the community level. As an example: It was very difficult to find a high-quality and (at least for some core discipline(s)) widely accepted publication outlet for interdisciplinary CSCL research until two years ago. The international Journal on CSCL (ijCSCL) helped to improve this situation. Also the funding situation changed recently as can be seen for example in the European Kaleidoscope project.

While this study provides a current snapshot of disciplines and interdisciplinarity in the CSCL community it would also be fruitful to trace interdisciplinarity throughout the complete CSCL conference series. This might lead us to a general pattern how interdisciplinarity evolves, develops and is utilized in a scientific community.

Acknowledgements

The authors thank Cindy Hmelo-Silver, Gijsbert Erkens, Yasmin Kafai and Nancy Songer for providing lists of authors and reviewers and for granting permission to use this data for our research. We are grateful to all participants of our study for their collaboration and timely response to our survey.

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Designing Collaborative Mathematics Activities for Classroom Device Networks

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Abstract: This paper explores the potential of networked devices to support classroom problem solving in small groups. We articulate two principles for designing networked collaborative activities: that they should 1) balance the group's collective engagement of shared objects with opportunities for individual student manipulation of those objects and 2) coordinate networked interactions among student-controlled objects with mathematically meaningful relationships. To illustrate these principles, we present a scenario for small-group collaboration involving classroom device networks.

Introduction

Networks of graphing calculators and handheld computers provide the potential for a range of new structures for classroom collaboration (Roschelle & Pea, 2002). In particular, connections among these linked devices can support networked interactions that complement conventional, face-to-face social transactions in the classroom. Computer-supported collaborative learning often takes one of two forms. In the first, participants engage one another at a distance, *through* the computer, such that the network serves as a substitute for or an alternative to collocated interaction. In the second, participants engage one another *around* a computer, such that the technology complements collocated interaction by providing a medium for coordinating words, gestures, or expressions. Classroom mobile device networks offer distinctive possibilities for simultaneously capitalizing on both of these collaborative modes; our work seeks to develop and explore that potential.

Classroom networks typically feature two interfaces: those available to individual students through their respective devices, and that of a server machine available for collective engagement through a projected display. Similarly, many classroom network architectures are organized around exchanges of information from student devices to a teacher's server and the reverse, rather than between student devices. Each of these constraints poses significant challenges for the design of collaborative activities among small groups of students within a whole-class network. This paper explores network topologies and task designs that address these challenges in order to fulfill what we see as the collaborative promise of networked devices. To that end, we identify two key principles in the design of collaborative activities for classroom networks, and then describe a prototype design representing our efforts to enact those principles. The first of these principles involves balancing a tension between providing students with individual engagement of mathematical objects, and sharing control of those objects across the linked devices of multiple students in a group. The second principle emphasizes our interest in using important relationships among relevant mathematical objects as frameworks around which to organize corresponding networked transactions among devices, and collaborative interactions among students. These principles are elaborated in turn below.

Coordinated Control of Collective Objects

Our approach to conceptualizing small group collaboration is compatible with that of Roschelle and Teasley (1995), who define collaboration in terms of participants' ongoing efforts "to construct and maintain a shared conception of a problem." In that regard, we seek to develop problem-solving tasks around students' engagement with collective mathematical objects. Such objects are collective to the extent that they can be simultaneously examined and jointly manipulated by multiple participants. The objects of interest in this paper are mathematical phenomena such as functions, expressions, coordinates, shapes, or sets. We take such objects to be collective when they or their attributes appear—and change—simultaneously on the devices of multiple students, or when they appear in a shared display as a consequence of contributions from multiple students. Control of such objects might take the form of, for example, entering an algebraic expression, adjusting a parameter, translating a graph, editing a table, or moving a point. The issue of shared control, then, concerns the ways and the extent to which such object manipulations are conducted jointly. Does one student take responsibility for editing an algebraic expression while the others consult? Or does each student edit a parameter of a shared expression? Or does each student enter and alter her own expression? Personal devices can provide each student with the capacity to make independent contributions to networked collaborative activity. While this capacity affords rich opportunities for the participation and engagement of all students in a group, it also necessitates careful management of those contributions in order to ensure that they lead to productive collaboration.

Mathematically Meaningful Links

The second key element of our approach involves designing activities and problem-solving situations in which networked social relationships among students are aligned with mathematical relationships. In particular, both the ways control of objects is shared among students, and the ways resources and responsibilities are distributed among students, are organized so as to reflect important links among mathematical phenomena. This principle is closely related to Stroup, Ares & Hurford's (2005) notion of mathematics structuring social activity in networked classrooms. Because our designs target small groups of two to four students, they emphasize mathematical relationships of similar scale. The scenario presented in this paper, for example, highlights the unique linear relation specified by two distinct points in a Cartesian plane. Our collaborative activities are organized around network topologies that are based on this mathematical relationship, so that a student group might be defined by the network in terms of the curve specified by the set of points through which it must pass, each of which is controlled by a different student. The instructional goal of linking mathematical and social interactions in this way is to use the connections among students to make salient the corresponding connections among the representations and objects those students respectively observe and control—recognition and understanding of those mathematical relationships is a central learning objective for these designs.

Group-Level Graphing: Relating Points and Curves

This scenario uses the NetLogo modeling environment (Wilensky, 1999) and HubNet network tools (Wilensky & Stroup, 1999) in concert with the TI-Navigator 3.0™ graphing calculator network to situate collective objects shared by small groups in a public classroom display shared by the whole class. In this design, teams of two students jointly manipulate points and curves in a coordinate graph assigned to their group. A single machine projected at the front of the room functions as a server and a collective display for up to twelve groups. Figure 1 shows the respective graphing calculator screens and coordinate locations for a pair of students collaborating in a "Lines" activity, and Figure 2 shows their collective graph as it appear in the public display. Each student in this pair uses arrow keys on her calculator to control the location of a point displayed both on the personal device and in the shared graphing window. That student's point is paired with that of a partner so that the coordinates of their points collectively define a line. As each student moves the individual point controlled by her device, the collective display dynamically updates both the algebraic equation and the graph of the resulting linear function even as it is continually transformed by students' position changes. Students are asked to perform a variety of tasks in this setting, such as generating a new line that maintains the same y-intercept but features a specified new slope, or maintains the slope while adjusting the intercept. In order to complete these tasks, students must explore the relationships between their respective points and the shared curve as they learn to coordinate their movements toward the desired transformations. The "Lines" activity also allows two pairs of students to share the same graph (Figure 2). This enables each pair of students to collaborate within the pair but also enables interaction with the other pair on the same grid. By undertaking tasks involving generating parallel, perpendicular, intersecting or other relationships among these lines, students must coordinate their efforts with one another within and between pairs as they negotiate a complex set of relationships among points, and among the curves those points define.

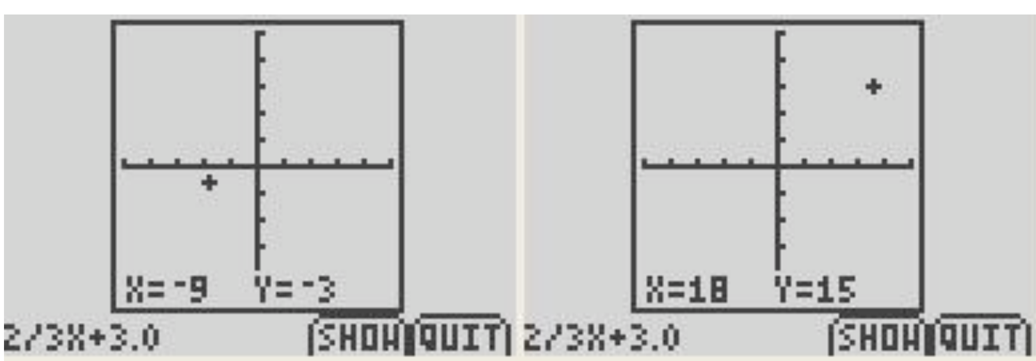

Figure 1. Two student calculator screens in the "Lines" activity.

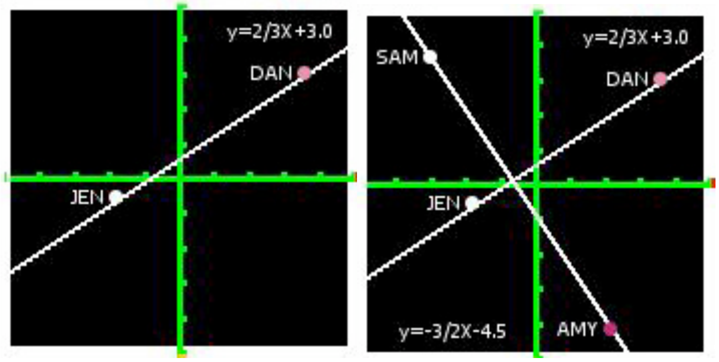

Figure 2. One and two student pairs in publicly displayed graphs.

The “Lines” activity illustrates our principles regarding both coordinated control and mathematical links. In each of these tasks, students control both an individual object, in the form of their respective points, and a collective object in the form of a line. While each student freely moves a distinct point, moving the line in accordance with various tasks requires two students to carefully coordinate those individual movements. Moreover, the relationship between these two students follows from the mathematical relationship through which two points in a coordinate plane uniquely determine a line. In the activities for two pairs of students and their respective lines, the social interactions among pairs correspond to a second level of mathematical relationships, namely among the linear functions generated by each pairs’ set of points. In each case, the tasks require students to reconcile their networked interactions with relevant mathematical relationships among the objects they manipulate.

Conclusion

The collaborative scenario presented in this paper represents one approach to negotiating the tension between collective ownership and individual control of mathematical objects, and to linking social and mathematical relationships in a problem-solving space. Different scenarios invariably enact these principles in different ways; we see the example presented here as a starting point toward exploration of a much broader range of collaborative possibilities opened up by classroom device networks. These two principles are by no means comprehensive with regard to collaborative designs in these connected classroom settings. Rather, they reflect themes that have been particularly salient in our initial implementation efforts and instructive in our designs to date. We expect that our continuing efforts to implement these networked problem-solving activities, and to design additional collaborative scenarios, will allow us to further expand and elaborate these principles even as we derive empirical insights into the nature and the effectiveness of the learning opportunities they provide.

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Acknowledgments

Support for the work presented in this paper was provided through a seed grant from Texas Instruments.

Online Video Repository and Supportive Community for Beginning Teachers

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Abstract: Nearly half of public school teachers leave in their first five years of teaching, and the inadequacy of their preparation is a significant challenge to their success. Teacher attrition results in part from frustration caused by inadequate preparation and lack of a professional development support system. Beginning teachers lack access to exemplars of effective teaching practices. This paper proposes a design framework addressing these problems via a free Internet-based resource for teachers to share videos of their teaching practices and exchange ideas through a supportive online community. This resource would present easily accessible videos of model practices, problem representations, problem solutions. The website would provide a supportive community for beginning teachers; enable them to: form groups centered on common interests, exchange messages, and offer one another feedback on teaching practices; facilitate sharing of classroom materials and best practices; and allow teachers to post profiles of professional and personal information.

Introduction

40% to 50% of all US public school teachers leave the profession in their first five years (Ingersoll, 2003), and the inadequacy of their preparation has been documented through outcome, observational, and self-report studies (Collinson & Ono, 2001; US Department of Education, 1999; Wanat & Cancino, 1996). Part of the attrition is due to low salaries (American Federation of Teachers, 2005; Ingersoll & Smith, 2003); however, part is due to teachers' frustrations caused by insufficient knowledge and skills (Department of Education Science and Training, 2002; MacDonald, 1999) and by lack of a professional development support system (Dymoke & Harrison, 2006; Johnson & Birkeland, 2003). With teacher attrition close to 50% in their first five years, the cost of teacher training is approximately twice what it would be without such attrition. Furthermore, beginning teachers' lack of adequate skills results in human costs of frustration and disillusionment for these teachers, as well as substandard educational outcomes for their students. Beginning teachers face numerous challenges in their induction into the profession: acquiring on-site knowledge of students, curriculum, and the school; developing appropriate coursework and lectures; implementing an initial repertoire of lessons; cultivating the classroom learning environment; creating a professional identity; and learning in and from practice (Feiman-Nemser, 2001). Teachers additionally encounter a variety of challenges throughout their careers, including broad problems such as how to maintain classroom discipline and how to motivate their students to learn, as well as very specific issues such as how to best teach a particular type of math problem. Current approaches to the development of beginning teachers' skills include the training they receive in their teacher education program, professional meetings, and professional journals. However, traditional teacher training programs are generally insufficient (McCormack & Thomas, 2003). Professional meetings are expensive for teachers to attend – costing time and money, including the need to hire substitute teachers to cover the classes of those at such professional meetings. Furthermore, few professional meetings present actual models or examples of effective teaching practices, and professional journals generally do not provide actual models of practices.

Multiple Internet-based distance learning tools have been developed to facilitate teacher education and professional support; examples include Teachscape, BEST, and Survive and Thrive Virtual Conference for Beginning Teachers. Teachscape (www.teachscape.com) provides an online resource for professional development training in teaching (Dede, 2003), which includes some video content of models of practice and interviews of experienced teachers and examples of coursework. The BEST (Beginning and Establishing Successful Teachers) website (www.uow.edu.au/educ/students/best.html) seeks to address the problem of teacher attrition by providing an online professional community for teachers through web forums and discussion boards, weblogs and sharing of curriculum materials (Herrington & Herrington, 2006). Survive and Thrive Virtual Conference for Beginning Teachers (www.survivethrive.on.ca) strives to support beginning teachers by providing online conferences given by experienced teachers on the following themes: literacy, working with parents and families, professional issues, classroom management, special education, and assessment and reporting. Limitations of currently available services include: (a) They do not permit the large-scale sharing of videos of teachers in practice; (b) They are not all free to use; (c) Their content is restricted behind registration and login barriers; (d) Social networking functionality is generally not available on the sites; (e) They lack a tagging functionality that would enable users to easily search for and access specific exemplars relating to teaching challenges facing them. This paper proposes a design framework to address the practical problems described above through the construction of a web-based resource for beginning teachers (see Figure 1). The resource would provide videos of models of teaching practice and serve as a supportive community for beginning teachers.

Video Representations of Teaching

Given the utility of exemplars of practices for those learning a set of skills (Woody, 2003), approaches to improve the performance of beginning teachers should provide multiple models of various aspects of teaching in a manner that is easily accessible to teachers. Research in educational psychology has shown that people with these representations do better work (Woody, 2003). By 'easily accessible', we mean inexpensive with respect to resources such as money and time, as well as convenient to teachers' schedules. The design of the website should follow the guiding principles of authentic learning environments, which include: realistic contexts and true-to-life activities (Brown, et al., 1989); access to expert performances and models of practices (Lave & Wenger, 1991); numerous viewpoints and roles (Spiro, et al., 1991); collaborative knowledge creation (Collins, et al., 1989); occasions for reflection (Boud, 1985); occasions for articulation (Lave & Wenger, 1991); mentoring and scaffolding (Greenfield, 1984); and authentic assessment (Reeves & Okey, 1996). The online video resource proposed here will have user-provided variety of representations of teaching problems and problem solutions. This approach also proposes to include a user-rating system to provide peer review of the video segments that are posted. The video-sharing website, YouTube (www.youtube.com), demonstrates that such an Internet video resource can feasibly be built and that video on the Internet is widely used. A limitation of this proof of concept is that YouTube is primarily a recreational resource rather than an educational resource, although YouTube certainly has the capability to deliver instruction. Nevertheless, the multitude of distance learning applications on the web such as Stanford Online (http://scpd.stanford.edu) and Harvard Distance Education (http://www.extension.harvard.edu/DistanceEd/) demonstrate that distance learning can be successful.

An Online Community for Teachers

This proposed research will provide an online professional community to support teachers. A supportive professional community for beginning teachers would help reduce attrition by minimizing new teachers' sense of isolation in the classroom. The website would include functionality such as the ability to join groups focused on topics of shared interest, the ability to: exchange messages, give feedback on teaching practice, share classroom course material and best practices, and post teacher profiles of professional and personal information. The online community would be a source of encouragement and inspiration for beginning teachers through their interactions with peers and models of practice. This resource would provide a means for beginning teachers to seek advice from peers and mentor teachers to help them solve specific practical problems facing them as they are inducted into the profession. Facebook (www.facebook.com) serves as a proof of concept that an online community can be created and used extensively. However, this proof of concept is limited in that Facebook is primarily a social, rather than an instructional resource, and restricted to predetermined communities, whereas the proposed approach would be open to anyone.

Additional Characteristics of the Proposed Approach

This resource would be free to users. The pilot project could be supported through government or foundation educational research and development funding. If the user-base grows, the website could be supported through advertising. A measure of the project's success could be the extent of site utilization (number of users). Some might argue that the approach proposed here is not practical, because privacy concerns make the display of children's faces problematic. The developers of the website could seed the video repository with only videos of teachers and not display the faces of the children or their names. Users of the site could be required to agree to the terms of service, which would specify that neither the faces, nor last names, nor any other personally identifying information of any minor or other individual besides the teacher would appear on the video. Thus, concerns about privacy would be addressed.

Figures

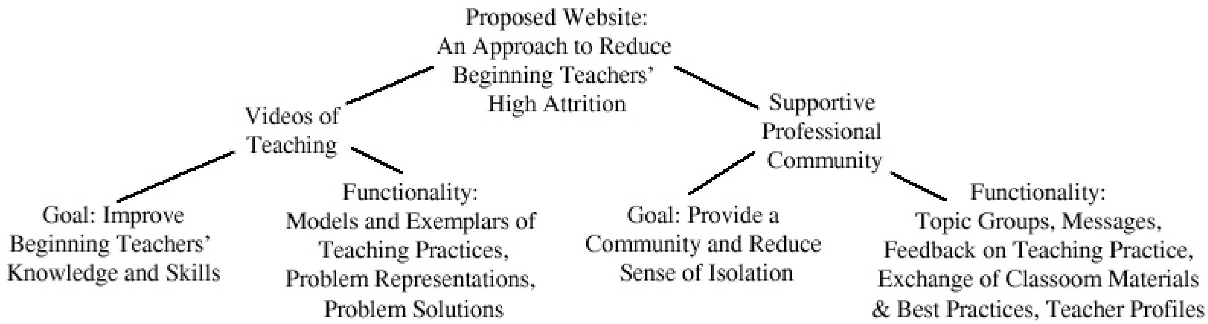

Figure 1. Proposed Website Organization

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Professional Visions in the Liminal Worlds of Graphs

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Abstract: A pair of comparable but contrasting episodes wherein biostatisticians narrate within the Cartesian space of regression graphs produced by software, illustrates how close analysis of narrations can reveal distinctive professional visions that correspond to differing views of work in biostatistical consulting or lecturing. Graphs serve as material anchors for conceptual blends that form the basis for narratives that merge Cartesian space with the space of artifacts from the setting from which the data came.

Introduction

Technical disciplines have distinctive material representations that experts tend to deploy more adroitly than novices. Experts invoke the privilege of coding and highlighting salient features of produced material representations in a way that constitutes a professional vision distinctive to that discipline (Goodwin, 1994). Indeed, to become an expert is to be "disciplined" to perceive accordingly (Stevens & Hall, 1998). A question for research is to explain how experts interact with novices to "discipline" their perception. In this study, I contrast how two biostatisticians spoke for the biostatistical practice of interpreting graphs, deploying them as medical researchers or other biostatisticians looked on. In these two brief selected episodes, both biostatisticians spoke in front of an audience beside screens illuminated by LCD projectors, about data summarized by graphical displays of regression analysis. But the biostatisticians differ in status: Steve is a Masters level biostatistician and Leonard is a full professor and head of the department. Steve spoke to an audience of researchers only, Leonard spoke to a group comprised of researchers and fellow statisticians. Furthermore, Steve had generated his graphs using SPSS, a proprietary, graphical user interface (GUI) software package that provides a limited menu of options for the user. Leonard was working with R, an open-source, code-driven statistical package that provides a vast array of options. These biostatisticians are properly considered to be experts in this situation, as they are situated within a familiar context (Roth, 2003) wherein they produced the graphs.

Because graphs summarize data by exploiting the human ability to reason spatially, readers notice different things depending on how they read *into* its spatial landscape and how they read *through* the lines, dots and labels to the laboratory setting from which the data came. In common with other professionals, such as physicists gathered around chalkboards (Ochs, Jacoby & Gonzales, 1994), the biostatisticians narrated and gestured as they created a liminal world that merged the interlocutors in the lecture hall, Cartesian space and the laboratory setting. Such merged spaces are evocative of conceptual blends (Fauconnier & Turner, 2002) for which graphs are potent material anchors, serving as a durable organizer of information (Hutchins, 2005) and a common reference for interlocutors to attend to and index by means of gesture (Williams, 2005). The purposes of this contrast are threefold. One, to simply catalogue narrations around graphs in a technological setting not yet well investigated from this perspective. Two, to briefly describe the liminal world of merged or blended spaces into which each biostatistician invited listeners to follow. Three, to determine who can follow the story and who cannot in order to illustrate how particular professional visions manifest in speech and gesture correspond to conflicting views on the role of the biostatistician in medical research.

The SPSS Episode with Steve

In this episode, Steve spoke about a graph depicting the weight of children compared to the difference between the energy measures from two devices monitoring the metabolic activity of children running on a treadmill: one, a closed chamber housed in the research facility (the "gold standard"), the other a portable armband device or "sensor". See Figure 1: He placed the variables into the GUI, and then invoked SPSS to produce the regression graph as output. To the right, a map depicts the words spoken in synchrony with hand tracings (words in transcript in synchrony with gesture are underlined, tracings in white in Figure 1). A member of the audience, “Brian” sometimes speaks as well.

1	Steve	*So, so this is our graph that we saw a significant correlation in. And here’s the weight. And here’s the difference between the, uh, armband and the chamber. So, above zero means that the armband overpredicts the energy expenditure. And here the armband underpredicts. So what, what conclusion would you make from that?*
2	Brian	*The lighter you are the worse it works?*
3	Steve	*The lighter you are the worse the armband works right? Mm hmm. And, and actually after a certain weight the arm band starts to=*
4	Brian	*=Oh, yeah*
5	Steve	*overpredict. And, and maybe this is because these, uh, children are more like adults and it’s, it’s working better here. In the lighter children it’s really, uhm, it’s really most off in, in the children who weigh less.*

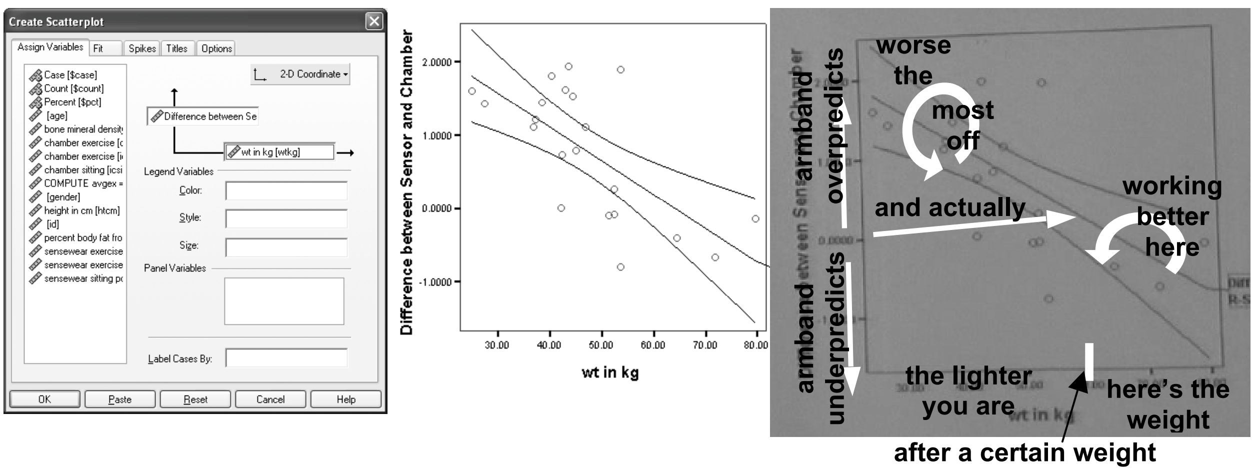

Figure 1. Reproductions of the GUI, the output graph and the marked up still frame from video.

The graph is a scatter plot with a regression line (equation not shown) and 95% confidence interval curves. Steve first highlighted the graph generally, each axis and the zero point on the ordinate axis. It was not necessary to code these features because they were generally understood at the outset. He then coded and highlighted regions where the armband overpredicts and where it underpredicts, thereby entering a liminal world where armbands from the laboratory reside in Cartesian space in view of Steve and his interlocutors. After Steve asked for conclusions (turn 1), Brian suggested a straightforward interpretation: less weight, worse performance (turn 2), employing a personal pronoun, predicate structure (Ochs, Jacoby & Gonzales, 1994) wherein the subject (“you”) diminishes his weight as the armband works progressively worse. Steve at first confirmed Brian’s overall interpretation, borrowing the same grammatical structure, but quickly disconfirmed Brian’s suggestion in part, using his left hand as if to emphatically slice through the graph from the zero point rightward until his hand reached the trend line (turn 3). He thereby re-highlighted the zero point, coded and highlighted a zero-value horizontal line, and reversed the direction of weight variation towards increasing values. Next, he coded “a certain weight” by using his right hand as if to slice the horizontal axis at the 60 kg tick mark. This was a critical value after which the armband will “overpredict” (sic, turn 5). I believe he meant to say, “underpredict”. He then recoded the armband reliability within this bottom right Cartesian space as “working better here” and coded the upper left Cartesian space as the location where the armband is “most off” (turn 5).

The R Episode with Leonard

Leonard has stated often that biostatisticians should interpret for researchers and envisions a future where researchers in the medical school rely on his department more. He hopes to offer them sophisticated analyses that only highly trained biostatisticians can do. He advocates R as a substitute for others, pointedly singling out SPSS for its reliance on outdated or inappropriate statistical methods. But few medical researchers can take the time to learn R, as it is not easily approachable to the statistical novice, especially anyone unfamiliar with programming. Leonard's short course on regression modeling was the setting for this episode, a retrospective analysis of passenger data on the Titanic. He posed the problem of how to determine patterns of survival among passengers, treating age as the principal input variable. He wrote out a single line of code, entered it and proceeded to talk about features of this loess regression graph while using his computer cursor to index locations as he spoke. The following short transcript is followed by a copy of the graph taken from the lecture notes (Figure 2).

The next thing we're going to do is some non-parametric smoother. This is gonna relate age to survival and put a rug plot on that graph. So you see we have less data in the young people and we have a very steep age drop here. This is, uh, like a sixty-five percent survival, down to forty percent survival and then it gets to be kind of odd. This is, this is what confounding looks like. So these are people of different class and sex and we're mixing those all in. We don't account for that in this kind of plot. But we're starting to see at least overall, once you get to about age twenty, maybe that gets counted as an adult, but there's a lot of slope here saying there's no unique cut off for what is a child. It's just the closer you are to being an infant, you have a higher chance of getting put on the lifeboat. So now we're gonna start to stratify that.

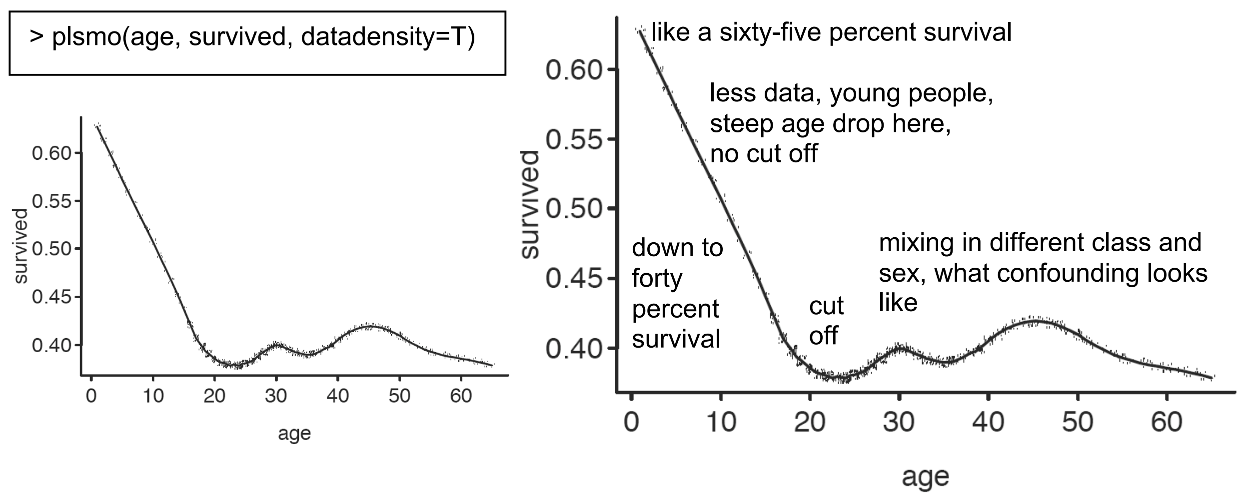

Figure 2. The R code (boxed above) used to generate the graph at left. At right are the areas he indexed.

The graph is a loess regression plot with a dot near the curve for each person by age, enigmatically depicting people as having survival probabilities intermediate between 0 and 1. Briefly put, this is a difficult artifact to use as a material anchor for most medical researchers and arguably for many biostatisticians as well. Leonard invited his audience to entertain (by means of computer cursor movement) different locations where people reside within the Cartesian space. The liminal world at times merges Cartesian space with a space not of people and boat, but filled with other such graphs, with many possible graphical trends, some of which look like this undulating and "confounding" trend.

Distinctive Professional Visions

We find in Steve's narrative an attempt to bring the experimental setting into Cartesian space in order to teach researchers how to deploy SPSS outputs as interpretive tools. In contrast, though Leonard does narrate liminal worlds uniting Cartesian space with the people on the Titanic, he also describes places where "confounding" occurs, a space where only other biostatisticians can enter and only R can help produce. Though these are only two short episodes, selected for purposes of contrasting similar situations (biostatistical talk about regression graphs), they are representative of talk from each biostatistician over the hours of video gathered from each. Steve never creates spaces that medical researchers cannot enter through Cartesian space, whereas Leonard often does so. Professional visions differ where practice differs, especially where routine practice is under fire from reformers, as is certainly the case in biostatistics (Sterne & Smith, 2001). These biostatisticians stand on opposite sides of the controversy. Steve needs his clients to do most analysis by themselves and therefore needs for there to be such a thing as routine analysis, a task for which the user-friendly SPSS is designed. Leonard advocates more computationally intensive and more assumption-free approaches that have become increasingly influential in the last twenty years but that entail dependence on biostatisticians for grants to be funded or papers published. Each narrates stories that correspond to his understanding of how future work is to be shared with clients. How experts narrate over Cartesian space reveals distinctive professional visions (ways of seeing) that correspond to distinctive views on how professionals do the discipline. Close analysis can be an effective tool for understanding technoscientific work practices, especially where parallel information about participants' practice can be used to provide a broader picture.

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Acknowledgments

Research reported in this article was supported by NSF grant REC-0337675 to Richard Lehrer, Leona Schauble, and Rogers Hall.

Fostering Students' Participation in Face-to-Face Interactions and Deepening Their Understanding by Integrating Personal and Shared Spaces

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Abstract: In this research, we introduced *CarettaKids* into the social context of a classroom environment to evaluate whether integration of personal and shared spaces can help promote students' participation in synchronous/co-located interactions in the classroom and deepen their understanding of subject matter. Analysis of videotaped interactions and pre- and posttests clarified the following three points. (1) Students who used *CarettaKids* presented the simulation results and rules for object arrangement they worked out individually in their respective personal space, by using *CarettaKids*' function of projecting object arrangements and simulation results from a personal digital assistant onto a sensing board. (2) Many of the students who used *CarettaKids* examined individually generated ideas collaboratively in the shared space. The patterns of collaborative examination are: (a) Induce a rule for object arrangement from object arrangements devised in personal spaces; (b) Deduce a new object arrangement from the rules discovered in the personal spaces; and (c) Refine the rules discovered in the personal spaces through group discussion. (3) Students who used *CarettaKids* not only considered all of the three factors, i.e. residential area, industrial area and forest area, but also understood relations between these factors, thereby deepening their understanding of city planning that takes environmental and financial aspects into consideration. We suggest that the degree to which students deepen their understanding is affected by the presence or absence of collaborative examination of individually generated ideas in the shared space.

INTRODUCTION

In the field of computer supported collaborative learning (CSCL), less research has been conducted on support for synchronous/co-location interaction than on support for other types of interaction (Lonchamp, 2006; Scott, Mandryk, & Inkpen, 2002). However, in the social context of the classroom, students learn not only individually, but also collaboratively while interacting face-to-face with the teacher and other students in the same classroom. Therefore, while amplification of classroom learning is defined as the main agenda of the CSCL research field, working more actively on computer-mediated support for synchronous/co-location interaction is more necessary than ever before.

Regarding computer-mediated support for synchronous/co-location interaction in the classroom, several systems for providing a socially shared space have been developed and evaluated (Suthers, 2006). One system has been developed in which students input information by operating three-dimensional physical objects and the input results are superimposed on the physical objects (Arias, Eden, & Fisher, 1997). This system not only allows simultaneous input from about six users, but also can integrate the computer-supported shared space seamlessly with the face-to-face interaction in the classroom. Because of these characteristics, this type of system helps increase students' feelings of being immersed in collaborative learning, while promoting shared interaction (Eden, 2002). Furthermore, this type of system can support a high level of collaborative problem-solving performance by elementary school students (Sugimoto, Kusunoki, Inagaki, Takatoki, & Yoshikawa, 2003).

However, this type of system has two problems with respect to individual students' interaction in shared space: (1) Some students do not present their own ideas in the shared space; (2) The ideas generated by some individuals are not examined by others in the shared space (Fischer & Sugimoto, 2006). These problems are associated with a lack of feedback on individual ideas from other students, and are considered important causes of inhibition among students that prevent them from deepening their understanding through participation in collaborative problem-solving activities in the shared space. Once these problems are overcome, however, it will be possible to add a new advantage to the existing system (i.e. support for individual cognition), without impairing its existing advantage (i.e. support for group cognition).

By using hand-held devices, we have attempted to create a personal space in which individual students can work without being disturbed by other students, and to integrate individual personal spaces into the existing shared space. The approach to creating a personal space using a hand-held device has been attempted in other CSCL research projects, achieving some positive results (e.g., Iles, Glaser, Kam, & Canny, 2002; Roschelle, Rosas, & Nussbaum, 2005).

We have developed a system called *CarettaKids* (Deguchi, Yamaguchi, Inagaki, Sugimoto, Kusunoki, Tachibana, Yamamoto, Seki, & Takeuchi, 2006; Sugimoto, Hosoi, & Hashizume, 2004). This system uses a sensing board based on the radio frequency identification (RFID) technology to support collaboration in a shared space, and a personal digital assistant (PDA) device to support activity in personal spaces. This system enables students, in collaboration with one another, to simulate city planning with consideration of environmental and financial aspects. However, no evaluation has been conducted on the effectiveness of *CarettaKids* in the classroom setting. More specifically, it has not yet been evaluated whether *CarettaKids* is effective in supporting students' generation of ideas and careful examination of others' ideas in the shared spaces and deepening the understanding of individual students.

RESEARCH QUESTION

Our study aimed to answer three research questions. (1) Were the students who used *CarettaKids* able to propose ideas in the shared space that they had generated in their personal space? (2) Did the students who collaboratively used *CarettaKids* examine the individual proposed ideas in the shared space? (3) Were the students who used *CarettaKids* able to deepen their understanding of city planning that concerns environmental and financial aspects?

METHOD

Participants

The curriculum that used *CarettaKids* was implemented in a sixth-grade class (33 students aged 11 to 12 years) in a university-affiliated elementary school in Japan. The class was divided into six groups (Groups 1–6), each comprising five or six students. Each group was provided with one set of the system. None of the students had used the system before. One of the authors was the teacher. She had more than 10 years teaching experience and had knowledge in science education and biology at bachelor's degree level participated. All the other authors participated in the class for purposes of data collection and technical support.

Curriculum

The curriculum was designed for creating the situations that allow students to move seamlessly between the two spaces using *CarettaKids*. So, three types of activity (shared-space, personal-space, and mixed-space learning) were included in the curriculum. And the curriculum was designed for creating the situations that allow students generate ideas and examine others' ideas using *CarettaKids*. So, the learning cycles consisted of three types of activity were repeated several times and the inter-group interaction activity was included in the curriculum.

Data sources, measures, and analyses

Regarding the evaluation methods for answering the three research questions, for Questions (1) and (2), the interaction analysis (Jourdan & Henderson, 1995) was used to analyze videotaped records of the students' classroom activities; and for Question (3), pre- and posttest analyses were conducted.

RESULTS

Analysis of videotaped interactions and pre- and posttests showed three main findings. (1) Students who used *CarettaKids* presented the simulation results and rules for object arrangement they worked out individually in their respective personal space, by using *CarettaKids*' function of projecting object arrangements and simulation results on the PDA onto the sensing board. (2) Many of the students who used *CarettaKids* examined individually generated ideas collaboratively in the shared space. The patterns of collaborative examination are: (a) Induce a rule for object arrangement from object arrangements devised in the personal spaces; (b) Deduce a new object arrangement from the rules discovered in the personal spaces; and (c) Refine the rules discovered in the personal spaces through group discussion. (3) Students who used *CarettaKids* not only considered all of the three factors, i.e. residential area, industrial area and forest area, but also understood relations between these factors, thereby deepening their understanding of city planning by taking environmental and financial aspects into consideration. We suggest that the degree to which students deepen their understanding is affected by the presence or absence of collaborative examination of individually generated ideas.

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ACKNOWLEDGMENTS

This research project has been supported by Grant-in-Aid for Scientific Research (B) (No. 16300248) and (A) (No. 18200048).

Understanding Classroom Culture Through a Theory of Dialogism: What Happens When Cheating and Collaboration Collide?

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Abstract: We consider tensions between collaboration, ownership, and appropriation in relation to Mikhail Bakhtin's theory of dialogism. We analyze examples of these tensions from our own research in an after-school, design research program and relate them to findings from other research that explored using collaborative learning systems in classrooms. We apply dialogism to describe factors that contribute to students' perception of these classroom experiences as ones that do or do not foster collaboration, including the culture of the classroom, the affordances of the technologies used to mediate collaboration, and the role of multivocality in the classroom. Students are using, reusing, and appropriating media in creative ways outside of their school settings while teachers are increasingly incorporating related emerging technologies such as wikis, blogs, and chat rooms into their classrooms. By understanding the factors that contribute to dialogism, educators will be better equipped to create classroom cultures and design environments to encourage collaboration among students.

Introduction

Youth are actively and enthusiastically creating and producing digital content in their online computer mediated environments. Recent studies have shown that 57% of teenagers have created a blog or webpage, posted original artwork, photography, stories or videos online, or remixed online content into their own new creations, 33% have shared what they create online with others, and 19% have created new works by remixing content they appropriated from another source (Lenhart & Madden, 2005). While youth are freely engaging in activities of content creation, media use, reuse, and remixing, the interplay of these practices and behaviors within the context of their schooling environments is more complex. Students' culture of sharing, copying, and pasting media in their daily informal practices online often lies in contradiction to the notions of plagiarism, stealing, and cheating that have been instilled in them within their classrooms. Even though culturally accepted literary masterpieces such as the Odyssey, the Iliad, Mort d'Arthur, the Sistine Chapel, and various works by Shakespeare are the products of appropriated and remixed content (Jenkins et al., 2006), students' online practices of remixing through blogging, manipulating images, audio remixing, making digital movies, and creating customized game modifications may be less well accepted in classroom environments.

Social communication sites on the web like MySpace, Facebook, and Wikipedia are rapidly growing in popularity. This growth, in combination with the increasingly globalized socially networked information economy, indicates a need for researchers, teachers, parents, and policy makers to better understand the influence of these media and activities on the changing dynamics of classroom collaborative culture. In this paper, we discuss the tensions that occur between remix culture and classroom culture, focusing on new media and computer science environments in particular. Our use of the term new media, in this context, refers to the many technologies and online environments that students use in their daily lives, including blogs, wikis, chat rooms, instant messaging, social networking sites, as well as their use of cell phones and handheld mobile devices. We highlight examples from our research which reveal how these contradictions played out in students' informal learning environments. We then apply Mikhael Bakhtin's theory of dialogism as a framework through which to address these tensions in order to design a culture of collaboration in classroom learning environments.

Collaboration or Cheating?

Researchers in CSCL have described ways in which the creation of artifacts such as words, texts, images, sound, and video can contribute to the collaborative knowledge construction process (Stahl, 2003; Suthers, 2005). One theory of learning that is used to describe this process is constructivism, which describes the importance of deriving meaning through learners' interactions with their environments (Piaget, 1976). Constructivism helps to explain how learning occurs through appropriation as the assimilation of concepts within a learner's internal mental processes of making knowledge his or her own. However, its intention was not to explicate appropriation as the borrowing, reusing, or incorporation of others' ideas and tangible artifacts during a learner's actual processes of construction (Ackermann, 2004). In describing the nature of communication, Bakhtin describes all communication as consisting of continual acts of appropriation in the latter sense: “The word in language is half someone else’s. It becomes ‘one’s own’ only when the speaker populates it with his intention, with his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention” (Bakhtin, 1986, p. 293). In the first use, constructivist learning through appropriation is encouraged. In the second use, in the context of Bakhtin’s definition, appropriation can imply copying, plagiarism, stealing, or cheating, even when used in the way that Bakhtin intended.

The dichotomies between these two interpretations of appropriation can lead to contradictory perceptions of what rules should guide their use of new media in the classroom. The historical transmission view of learning that has dominated classroom practice views dialogue as a one-way interaction (Heap, 1985). Knowledge is imparted from the teacher to the class, and students then apply that knowledge through the practice of “question, answer, evaluation,” which Lemke (1990) referred to as the Triadic Dialogue. Appropriation enters into the mix when students are encouraged to dissect, transform, and share artifacts and ideas as part of their individual and collaborative learning processes. While part of the learner’s process is to make content personally meaningful, what are the implications when a personally meaningful artifact, in fact, belongs to another person? In other words, what are the boundaries that define copying an idea versus copying an expressive form (1)? Researchers in computer science education have long questioned the role of collaboration in assignments, looking to understand at what point collaboration ends and plagiarism or cheating begins (Stewart-Gardiner et al., 2001; Sheard et al., 2002; Harris, 1994; Roberts, 2002). When should teachers encourage students to collaborate? Should the students discuss the ownership of that code? If ownership is not properly acknowledged or attributed, are they cheating? Where does the line fall between collaboration and cheating? In the following section we describe examples from our research which reveal how these questions emerged.

Backyard Transformations: A Case Study

We conducted a two-month, after-school program at a local public school as design research. Our goal was to determine requirements for an online, collaborative storytelling environment to help youth learn principles of non-linear, narrative construction using multiple digital and physical expressive media. Storytelling is a valuable educational activity through which learners explore and make sense of the world around them. The story creation process involves developing ideas, acquiring understanding, and constructing knowledge through personally meaningful forms of self-expression. Recent projects have looked to design interactive storytelling environments to support the creation, production, consumption, and sharing of stories (e.g. Antle, 2003; Benford et al., 2000; Cassell and Ryokai, 2001). In our study, we conducted hour and a half long sessions, twice a week, at the school’s computer lab (see Figure 1). We provided four Apple Mac OS X desktops in addition to the school’s lab machines. The study involved eight fifth-grade students, five boys and three girls, and a team of five researchers (2). Our lead researcher ran each session, with support from the other researchers, who played the interchangeable roles of participant observer, note-taker, videographer, and teaching assistant. We videotaped all the sessions and conducted interviews with the participants to better understand their use of digital media in their everyday lives outside of school.

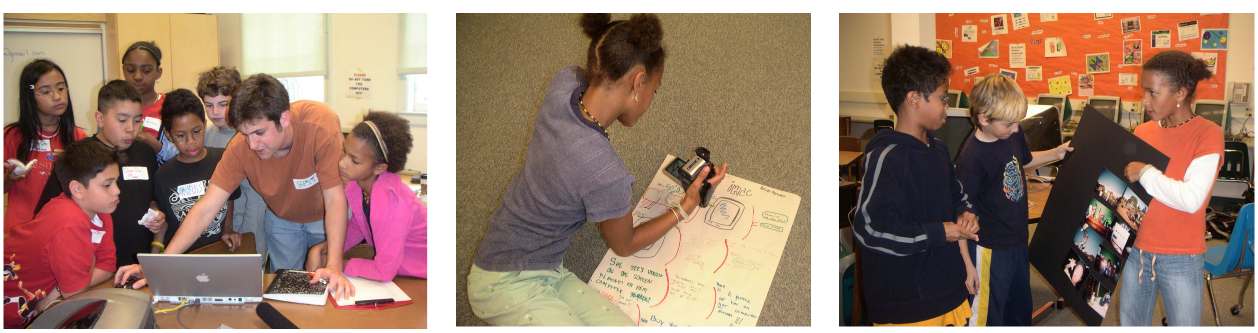

Figure 1. Backyard Transformations sessions.

We designed the curriculum to teach fundamental storytelling concepts, with each session focused on a particular theme, such as non-linear narration or character development. Our curriculum was modeled after Backyard Transformations, a narrative story construction research project conducted by Jill Wright and Rachel Strickland at Apple Computer’s Vivarium Research Lab from 1988-1991 (Strickland, 1991; Strickland & Wright, 1990). They had filmed 174 video clips and had created a corresponding set of printed cards to be used as prototypes for storytelling games. Their scenes were designed to encourage children's imagination and play through evocative and unusual character scenes. We pre-installed the video clips into Apple iMovie at each station and also explored using alternative digital tools such as Comic Creator, and FlashCan Animator (see Figure 2).

Figure 2. Comic Creator, FlashCan Animator, and iMovie with Backyard Transformations clip.

In addition, we provided participants with a disposable camera, their "Personal Card Creator," which they could use to take pictures outside of our sessions. We also provided a digital camera and video camera available for their use during each session. We encouraged them to incorporate drawings, paintings, photographs, and whiteboard sketches into their stories. Our activities ranged from highly structured, such as "extension of process of description to include techniques of association and relationship," in which participants were dealt fifteen cards and had two minutes to sort them into three categories of their own choosing, to highly unstructured, such as their final project, in which they created a complete digital story using media of their choice. Our activities fostered a culture that strongly encouraged media reuse and sharing, however, we did not attempt to establish any norms or rules for sharing, attributing ownership, or claiming ideas, artifacts, and stories as one's own. We thus observed that the participants struggled with a sense of uncertainty throughout their evolving storytelling processes. In our storytelling environment, who "owned" the components within their story sequences? In the next sections we illustrate the tensions that arose as participants appropriated and re-used each other's ideas in their own storytelling. Then, in the second half of the paper, we reintroduce Bakhtin's notion of dialogism as a way of resolving these tensions and thinking about the future of collaborative learning.

The "Creation" of Count Whistleboy: An Example of Appropriation

In the Backyard Tranformations card deck, a series of cards were made using the same "character." In one episode, Andrew came up with "Jackie, the Sumo Wrestler" from a card depicting a character its creators called "The Umpire." He also pointed out another card in his pile with The Umpire in shadows, which he described as "Count Dracula with a whistle." Toby then noticed that Jason had a similar card with the Umpire character, which he proceeded to describe during his presentation to the group (see Figure 3). During his presentation of "Count Whistleboy" Toby had appropriated Andrew's idea for a "Count Dracula with a whistle" and conflated it with the card in Jason's pile which contained a small person looking up with a whistle in its mouth.

> TOBY: This is a human. His name is Count Whistleboy. He is ten years old. He is ten inches tall. … And um it dislikes the … the dark… the moon the most because it goes "raar" and becomes a vampire. And um… and um… his friends are his whistles.

Figure 3. Images from "The Umpire" cards that became Count Whistleboy.

Throughout the course of the project there were other types of acts of appropriation. For example, Dionne created a story using a photograph of a cat that Iris had taken. Although Iris did not explicitly object to this use, did Dionne's act carry the same implications as the creation of Count Whisteleboy? When was borrowing from a peer collaborating and when was it stealing?

You Stole My Idea!

Participants preferred to collaborate during the idea generation process, often struggling to produce ideas on their own. For example:

> RESEARCHER: What do you like about working with other kids?
> ANDREW: I think it would go faster if I worked by myself but Miguel has some good ideas.… Miguel watches a lot of TV and gets good ideas from TV. There's a lot of good ideas on TV.
> IRIS: Giving me some ideas. Ideas are basically like all you need.
> MIGUEL: I like working with other people better 'cause usually I don't have all the ideas and other people can help.

However, while they sought out their peers and other external resources for ideas, they also expressed a desire to be given credit for ideas that were used by others. Following the Toby's creation of Count Whistleboy, Jason also decided to use the character in his own story, leading to confusion as to who "owned" the character.

> JASON: Wait, did you do Count Whistleboy or did you? [pointing first to Toby and then to Andrew]
> TOBY: I did Count Whistleboy.
> ANDREW: So did I.

Andrew initially showed little interest in Toby's use of the Count Whistleboy character, even though the character's visual appearance was modeled after his own Sumo Wrestler. However, Andrew's "so did I" in response to Toby's claim that it was his character indicates that he did in fact want to be given credit for his ideas. Toby did not object to this joint ownership and responded with a light-hearted expression of acceptance towards Jason's use. Their shared use of Count Whistleboy highlighted the important social aspects of building on and reusing one another's ideas as part of the development of group identity in their collaborative learning processes. However, not every conflict of ownership resolved without open conflict. In other instances, we heard comments such as "Hey, you stole my idea!" or "That was my idea!" In the following episode, Toby presented his story in iMovie to the group.

> TOBY: This is Madame Peacock.
> JASON: He stole the idea He stole the idea!
> TOBY: She's crawling because she has no feet. How do I know? I can't see her feet. She is 13 years old. She is small as a squirrel. It lives in a wooden house. Its favorite thing to do is hunt the Invisible Woman. … Their greatest hope is to destroy the Invisible Woman.
> JASON: [under his breath] Oh come on. [reaches across the table and points at the screen] He stole that. [points finger in Toby's face] You stole that!

The conflict was resolved when one of the researchers played a mediating role:

> RESEARCHER: [to Toby?] You stole that?
> TOBY: [giggle in acknowledgement]
> RESEARCHER: Well, I like it.
> JASON: Yes. That was my narrative movie thing.
> RESEARCHER: Well, I think that's a really good idea. Madame Peacock who chases the Invisible Woman… that's your character right?
> JASON: Yeah… well, that's his character [referring to the Invisible Woman]
> RESEARCHER [later, in the background talking to Jason] People use each other's characters all the time. It's not a bad thing. It's a good thing.

In this situation, Jason was less concerned that Toby had used the character of Madame Peacock and more concerned that he hadn't received credit for it.. In both stories, while tensions quickly dissipated when the "owner" was given public acknowledgement for his or her idea, character, or artifact, at the same time, their interactions brought to light the potential sources of complexity and confusion regarding the proper uses of shared artifacts. How should these practices, which are simultaneously individual and collaborative, be understood when the rules behind the sharing of ideas and artifacts are subtle or unclear? These examples both illustrate how the tensions played out in the classroom, but also point to a potential solution by suggesting a different lens for thinking about collaboration in the classroom that explicitly recognizes and appreciates acts of appropriation.

Dialogism in the Classroom

Bakhtin's theory of dialogism provides a framework through which to understand the culture of collaboration within learning environments. In particular, the perceived dialogic nature of a medium and how it is used in the classroom correlates to whether students will be inclined to use it collaboratively or individually. We use a definition of dialogue as consisting of one or more speakers, listeners, and the relationships between them (Bakhtin, 1981). Bakhtin (1986) used the term "utterances" to describe the situated act of dialogic discourse as a unit of analysis. Utterances begin and end with changes of speaker and they can only be defined in relation to other utterances. Each speaker's utterance "carries echoes" of the previous one as she appropriates and assimilates it into her own speech. We thus characterize dialogue as the inscriptions, implications, and intersections that accompany words, texts, gestures, intonations, voices, responses, and other communication utterances as they are interpreted and appropriated. While others have described the nature of dialogue as it occurs between man and machine (e.g., Meadow, 1970), we focus on dialogue as it takes place between man and man, where the machine is the mediating agent among two or more humans.

CSCL researchers have applied various dialogic theories to describe processes of meaning-making, knowledge building, language acquisition, and teaching thinking (Koschmann, 1999; Wegerif, in press; Roschelle, 1996; Wells, 2006; Wegerif, 2005). For example, Koschmann (1999), noting Werstch's (1998) prior work argues "utterances are not analyzable in isolation but must be studied instead with reference to the culturally-supplied mediational structures of which they are instantiations. Learning thus involves the process of multiple voices coming into contact, both within and across speaker-produced utterances." We draw from these studies to support our argument that increasing dialogism in collaborative learning environments can enhance students' knowledge construction processes. As noted by Bereiter:

> "Classroom discussions may be thought of as part of the larger ongoing discourse, not as preparation for it or as after-the-fact examination of the results of the larger discourse... The important thing is that the local discourses be progressive in the sense that understandings are being generated that are new to the local participants and that the participants recognize as superior to their previous understandings" (1994, p. 9).

In this paper, we do not look to analyze the types of learning and knowledge construction that occurred within our case study (although there is much more to be explored there). Instead, as prior scholars of Bakhtin have done (e.g., Kozulin, 1996), we extend and generalize Bakhtin's theory of dialogism in text and language to apply it to multiple modes of communication that are used in the classroom, such as audio, video, verbal, spatial, and gestural. While dialogic theory is relevant across a range of academic environments, for the sake of clarity, we focus primarily on its intersections within computer science and emerging new media. The following sections describe three factors that influence dialogism in the classroom that stood out as we considered our project in relation to other work and to Bakhtin's theory: dialogism through culture, dialogism through technical affordances, and dialogism through multivocality. We conclude with recommendations for designing collaborative classroom activities based on these three factors.

Dialogism through Culture

While students negotiate their common sets of rules, standards, and norms in their everyday interactions using online media, when in more structured learning environments, they look to teachers for direction and guidance in establishing these norms. At times, students' expectations of a particular environment can clash with teachers' expectations. For example, Guzdial et al. (2002) found that faculty attitudes and models of collaboration presented a cultural barrier to collaboration. Additionally, when they introduced software to facilitate collaboration, students from different disciplines had different experiences based on the culture within their discipline. Their findings supported those of Cohen (1994) who argued that students who perceive only one answer will not seek to collaborate, while open-ended and less structured assignments will encourage collaboration. Guzdial et al. found that students from computer sciences, who were used to grades based on individual coding assignments, resisted using CoWeb while students in architectural design, who were used to formal and informal dialogues, actively adopted the collaborative opportunities that were provided. CoWeb was successful when dialogue was a part of the disciplinary culture. *"If the culture of the context is not compatible, the medium will not succeed" (Rick & Guzdial, 2006).*

In our study, we generally did not seek to explicitly address or define rules for appropriation, although the example of Jason, Toby, and the conflict of Madame Peacock discussed above points to one exception. Additionally, we recognize that the way in which we structured our activities may have nurtured this conflict between our participants and their expectations in our project. In the case of Toby's use of Madame Peacock, the researcher intentionally chose a strategy to resolve the tension that would not be critical towards Toby's use of Madame Peacock, but would still ease Jason's anxiety by acknowledging the role that he played in the character's creation. This compromise, in a sense, reflects the tension in our own roles the classroom. From one perspective, we played the role of teachers assigning them tasks within the familiar context of their school's computer lab which normally followed traditional classroom rules and structures. However, from the other perspective, we were researchers running an after school program that was designed to encourage non-traditional explorations into creative media use. The participants therefore may have experienced conflicting notions of collaboration in the storytelling environment.

In this case, we might have avoided conflict and tensions regarding ownership by explicitly specifying rules and clarifying expectations to avoid potential misunderstandings. Many incidents of cheating in computer science courses have been due to the differences in awareness and expectations between students and teachers. If students perceive a clearly defined culture of dialogism, they will be better prepared to determine when collaboration is or is not encouraged.

Dialogism through Technical Affordances

The technical and material affordances of media influence the extent to which students perceive it to be collaborative in nature. For example, the interactions between Toby, Andrew, and Jason in their use of Count Whistleboy were undoubtedly aided by each of their abilities to pick up and physically manipulate the playing cards, point to cards in each other's piles, and place cards next to each other. Affordances of new media provide other these as well as many other novel opportunities for collaboration.

The potential of using of new media in schools is not a new discussion and its limitations in the classroom have been addressed within the field of CSCL. Researchers have long warned about the dangers of technological determinism caused by blindly introducing a medium into the classroom without considering its limitations (e.g., Pea, 1987). For example, new media environments such as distance learning and one-way communication tools like audio and video broadcasting were touted as powerful new tools for learning in the classroom. However, they also required substantial interactional structures through which to establish common ground and enable transformative communication rather than just transmissional communication (Pea, 1994, p. 291). CSCL thus emphasizes the importance of considering *how* the medium is implemented in the classroom based on its constraints and affordances. Dialogism is not embedded in the medium itself but instead emerges through the specific ways in which the medium is implemented and used within the learning environment.

Some educational software environments have been explicitly designed to encourage collaborative learning through carefully constructed uses of the medium's technical affordances. For example, DIVER is a "cultural remix tool for web video" that fosters "point of view" authoring for sharing, collaboration, and knowledge building around a common ground (Zahn et al., 2005). WebDIVER is an online version that allows DIVERs to upload a DIVE and share it with others who can then comment on the DIVE (see Figure 5). Through this process of "guided noticing" one participant guides the interaction and the other receives it. Although such prescribed roles will inevitably experience fluidity and an interweaving across boundaries during the collaborative knowledge construction process, the structure offered by the system provides an explicit and direct sense of ownership based on who is doing the guiding and who is the participant. Another example is Scardamalia and Bereiter's (1994) Computer Supported Intentional Learning Environments (CSILE). In CSILE, anyone can add a comment to a note but only authors can edit or delete notes (see Figure 5). The sense of ownership of a particular note is therefore made explicit. To copy a note and use it as one's own would be equated to stealing or cheating.

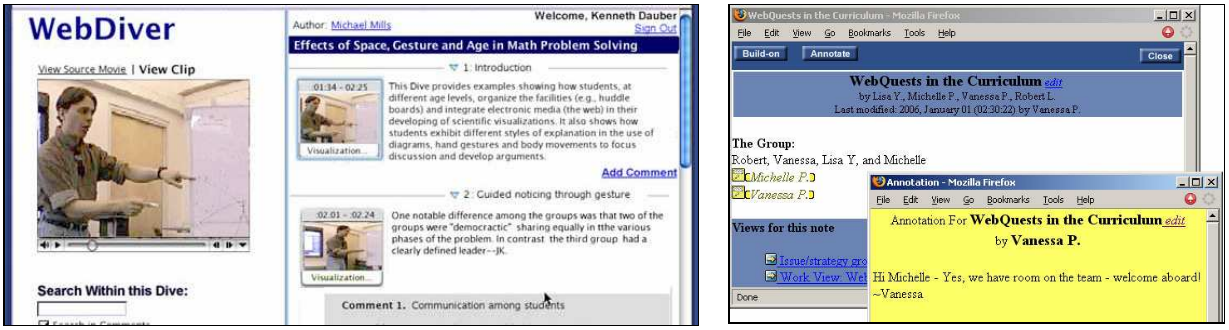

Figure 5. Guided noticing in WebDIVER and author edit box in CSILE.

Dialogism through Multivocality

The third important factor in designing for dialogism is multivocality. Multivocality is defined by Bakhtin as the ways in which multiple voices can be discerned in a text (Bakhtin, 1981). The role of multivocality in collaborative learning spaces is less clearly understood in these emerging new mediums. What happens when there are multiple voices, listeners, and possible interpretations in a given utterance? What implications, if any, does the speaker's original ownership have as the utterance evolves through multiple dynamic and untraceable states? In our study, for example, Miguel discovered a built-in sound pattern in iMovie and proudly maximized the volume to broadcast his find to the computer lab. Toby crossed the room to see the sound source and promptly incorporated it into his own story (see Figure 6).

According to Bakhtin, "Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated–overpopulated–with the intentions of others" (1981, p. 294). One of the challenges we faced was that, in contrast to text and language, which offer a more binary distinction between speaker and listener (although of course they are not always explicitly delineated), the boundaries are less obvious when the utterance continues to be used and reused beyond the speaker's original intention, as was the case in our multimedia environments. Multiple layers of meaning are added and interwoven as the utterance is appropriated throughout its lifecycle. Perhaps the sender's original message remains embedded somewhere in the medium but it will become convoluted and masked over time. The ability for messages to be mediated through both the students and the medium can influence the ways in which its dialogism evolves. What are the roles of the sender and receiver within these mediums?

Miguel's re-broadcast of his iMovie tune throughout the lab is a type of "indirect speech," which Wertsch & Toma (1995) describe as instances in which speakers incorporated text from prior talk. They discuss examples of indirect speech in their analysis of fifth grade students' discussion of a balance beam experiment:

> "It is reasonable to expect that when the dialogic function is dominant in classroom discourse, pupils will treat their utterances and those of others as thinking devices. Instead of accepting them as information to be received, encoded, and stored, they will take an active stance toward them by questioning and extending them, by incorporating them into their own external and internal utterances, and so forth" (p. 171).

Because the students are actively interpreting these utterances, the boundary between speaker and listener–and unanticipated future listeners–is not clearly demarcated. It is instead an inclusive dialogic space in which multiple forces mutually construct and re-construct one another. Wegerif (in press) argues that "any sign taken to be a mediation between self and other, a word or a facial expression, must pre-suppose the prior opening of a space of dialogue within which such a sign can be taken to mean something." Similar to Wegerif's description of these meaningful signs in dialogic spaces, we found that the affordances of audio and video mediums can enable "shoulder-to-shoulder collaboration" (Benford, 2005), even when participants are spatially located across the room from one another, as was the case with Miguel's broadcast. Thus, the implementation of the media and the multiple voices it may contain, which are also fluid and can evolve dynamically over time, will influence the ways in which the students choose to use it in their collaborative activities.

Figure 6. Examples of multivocality in Backyard Transformation activities.

Dialogism Out of the Classroom

Many of today's new media technologies are highly social in nature. These environments, such as MySpace and YouTube, have multiple social and communicative characteristics. For example, the explicit culture of sharing in YouTube is conveyed through the URL and Embed links that are prominently displayed next to each video segment, in which embedding linking can be explicitly enabled or disabled (see Figure 4). This external representation enables a fluid interaction through a shared understanding among users. It is made clear that new content can be shared by others who are free to adapt and appropriate the material to generate their own meanings. These features are designed to be used by multiple parties who contribute to or participate in the community, whether as active contributors, readers, or lurkers. Technical features like linking, tagging, and commenting can help to create a culture of dialogism within the software environment.

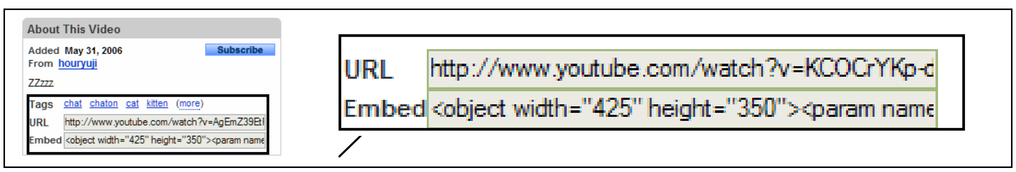

Figure 4. YouTube URL and Embed features.

Although the contexts of use of the environments we have discussed, from digital storytelling tools to online social communication sites to educational software, differ significantly, there are common threads across them as dialogic mediums. It is useful to ground our discussion of these varied learning environments by describing them in terms of categories of genres. Bakhtin described speech genres as characteristic patterns of speech within the realms of dialogue and text , which can vary from simple forms such as greetings, farewells, congratulations, or information about health, to more complex forms such as novels, dramas, or scientific research (Bakhtin, 1986, p. 69). Again, we extend Bakhtin's theory to describe various modes of dialogue across multiple media. If a software coding environment in computer science is consistently perceived to be a dialogic genre, the technical affordances that are core properties of that genre can convey to the student how it should be used, according to the designers of the software. Embedded features such as "publish my code to the class" or "download module from group" can help the students to perceive their actions using these features as collaborative, rather than cheating, as they engage in a dialog with the software designers through the medium. Koschmann (1999) states that this "involve[s] understanding not only the degree to which learners appropriate particular genres… but also the degree to which the genres themselves afford opportunities for the expression of the multivocal aspects of learner-produced utterances." The genre might provide the option for students to associate their name to a section of code–their "utterance"–in order to maintain a sense of individual ownership within the group's final artifact. If the authorship option is disabled, students will be made aware that their code contribution will be incorporated into a group-owned artifact that may not acknowledge individual ownership. In each of these examples, if the teacher can control these types of features by enabling or disabling options during certain phases of students' projects, the students will be more clearly cued into the extent of the dialogic, and accordingly, the collaborative, nature of their activities.

Conclusion

Many schools and universities are actively designing innovative teaching pedagogies and curricula by applying new media to traditional academic disciplines. For example, Harvard Law School is teaching its Law in the Court of Public Opinion course in an online 3D virtual world called Second Life (3), the Georgia Institute of

Technology is teaching computer science through an innovative media computation undergraduate course (4), and Byrd Middle School is teaching medieval history through a MySpace-like socially networked blog (5). This paper contributes an alternative perspective for designing and analyzing collaborative learning environments through the framework of dialogism. At the same time we explored open questions about the framework's applications in emerging mediums.

We propose that educators and designers can construct collaborative learning environments by considering the interdependent issues of culture, affordances, and multivocality through the lens of dialogism. These insights can help enable researchers in CSCL to guide students to make more informed and educated decisions in their individual and collaborative activities. Given the growing ubiquity of new media as a part of students' lives outside of school and the increasing use of these technologies as a part of classroom activities, we need to teach students the skills for developing digital literacies and critical reflection. As they transition into today's media rich, globally networked professional economy, they will need to understand the implications of sharing, collaboration, ownership, credit–and cheating–in these emerging interwoven environments of their everyday lives.

Endnotes

(1) The question of the implications of copyright issues and the division between transformation of a work versus simple derivation of a work is an important, but separate, discussion.
(2) Pseudonyms are used to protect the identity of the participants. All media is reproduced with the consent of the participants and their parent(s).
(3) http://blogs.law.harvard.edu/cyberone/
(4) http://coweb.cc.gatech.edu/mediaComp-plan
(5) http://byrdmiddle.org/richard3/?page_id=2

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Acknowledgments

We thank the Digital Youth research group at UC Berkeley's School of Information for their encouragement, especially our advisor, Dr. Peter Lyman. We appreciate the dedicated support of our fellow research team, Rachel Strickland, Carrie Burgener, and Nick Reid. We also thank Jill Wright, Greg Niemeyer, and the MacArthur Foundation for their time and resources, Thanks are also due to the reviewers for their comments and feedback. Finally, and perhaps most importantly, we thank the eight fifth grade students for their enthusiasm and participation in this collaborative learning experience.

Exploring the Potential of a Handheld Participatory Simulation and Social Network Application for Revealing Decision-Making Processes for Information Seeking Amongst Middle School Students

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Abstract: In this study a participatory simulation called the *Discussion Game* combined with TeCFlow, a temporal social networks visualization program is used to identify socially and cognitively-oriented rules for selecting discussion partners. Whereas, the majority of rules for previous interactions are based on social or random factors, after studying social network graphs, students cite more cognitive or informational factors as reasons for who to talk to.

Theoretical Considerations and Research Focus

Recent research on networked handheld applications has focused on how they can be used to influence the development of core CSCL skills and processes such as inquiry, collaboration, communication, decision-making, motivation, engagement, assessment, and information access (Clyde, 2004; Colella, 2000; Klopfer et al., 2004; Klopfer et al., 2005; Relan et al., 2003; Yoon, in press; Zurita & Nussbaum, 2004). Research on a subset of handheld applications called participatory simulations (Klopfer et al., 2005) that embed students in face-to-face simulations of complex events have been particularly valuable in demonstrating how technological affordances can be leveraged to support the acquisition of complex problem-solving skills such as multiple perspective taking (Yoon, in press). Social network analytic tools have also been used to promote CSCL processes although applications of this sort have been relatively fewer in education. Gloor (2006) found that by applying social network analyses to their own online communication patterns in a university course, students were able to improve communication behavior in virtual group activities. The exploratory work reported in this study aims at understanding the educational potential for an intervention that uses a handheld participatory simulation and social network application to reveal decision-making rules about who students want to talk to in order to share and gain information about a new science topic. It follows from previous research results (Yoon, in press) that demonstrated, amongst other things, that visual feedback of individual opinions on a topic, provided middle school students with information about their relative position in the classroom network and who they wanted to discuss their opinions with. The specific goals for this study are: 1) to investigate what participatory simulations coupled with social network analyses reveal about students' decision-making processes; and 2) to investigate how students use information gleaned from social network graphs to make peer selections.

The handheld participatory simulation used in the study is called the *Discussion Game* (Yoon, in press). In this game, participants are asked to rate an issue on a Likert-scale from -5 (completely unacceptable) to +5 (completely acceptable) and provide a rationale for their rating. Participants are required to exchange their ratings and rationales with other participants via the infrared *meet* function on the handheld and are asked to hold discussions with each other about their positions. After discussions, participants are encouraged to reflect on what they heard and change their positions. Interactions are archived on each handheld and collectively uploaded to a social networks visualization software program called TeCFlow which computes the information and provides a visual graph of the communication network created from the game.

Methodology

Volunteers for the study were recruited from two urban middle schools in West Philadelphia. The program was advertised as an intensive academic camp held over two weeks during the summer, with a curricular focus on cell biology and genetic engineering. Nine females and six males participated. All students were African American, eight students from one middle school and seven from the other and all scheduled to attend grade 8 in the fall of 2006. The study took place over 10 days in a two-week, 40 hours of instruction time frame in August 2006. Students explored a number of teacher-selected and student-selected multimedia and print materials that presented information on genetic engineering of animals and plants. Curricular concepts covered from the School District of Philadelphia's grade 8 core curriculum were DNA, chromosomes, genes, sexual and asexual reproduction, and mitotic and meiotic cell division. Throughout the program, students were asked to reflect on information learned about the effects of current genetic engineering research on human and non-human species. Five *Discussion Games* were played over the course of the intervention. The specific question addressed in the game was: *Genetic* *engineering research and applications are acceptable*. The data reported here were obtained from the five social network graphs generated from the games and responses from three questions taken from a social networks survey administered during the latter half of the program (on the seventh day of the ten day program): 1) Who have you spoken to most consistently over time and why?; 2) What are the rules by which you make choices about who you want to talk to?; and 3) Look at the last graph. Who on the last graph would you like to talk to most in the next game and why? Themes and categories were discussed and negotiated amongst the researcher and a graduate assistant and 98% interrater reliability was obtained from two independent raters.

Results

Students identified five rules by which they made choices about who to talk to in the *Discussion Game*. In some cases, students identified more than one rule. Table 1 shows the rule and frequency in student responses.

Table 1: Rules by which students made choices and frequency of responses.

Rule	Frequency
Talked to friends or people I was familiar with	7
Random, no rules, talked to anyone who was available	6
Talked to people who had a different rating than mine	4
Talked to people who had a similar rating to mine	1
Talked to people who had the most information	1

As shown in Table 1, the predominant rule by which students made choices about who to talk to was based on familiarity or friendship prior to studying the graph of interactions. As a cross check, responses from students about who they talked to most consistently over time and why produced similar findings in that 9 out of the 15 students identified a friend or person from their school. It should be noted that this pattern of choice was anecdotally observed to be fairly consistent over the first six days of the program prior to administering the survey and students were continually instructed to make decisions about who to talk to based on selection criteria other than friendship. Despite these instructions, only one student followed the rule of choosing people who had the most information. This student wrote, "The rules I went by are people who had the most important facts because it keeps my mind changing." Although the set of rationales produced to support student ratings is yet to be analyzed, anecdotally, this student showed the greatest growth in conceptual understanding as well as the most balanced evidence-based perspective by the end of the program.

Student responses to the third survey question about who on the last graph they wanted to talk to most and why, provided more encouraging results. After reading the graph (Figure 1), 12 out of the 15 students indicated that they wanted to talk to Chris (who had a rating of 5) in the next round and 2 out of the 15 wanted to talk to Jamie (who had a rating of -5). The remaining student Chris himself wanted to talk to Jamie. Figure 1 shows that by the seventh day, most students were selecting ratings in the middle range. Thus, selecting students who had ratings vastly different than their own appears to represent a shift in their selection strategies. Reasons given for their selections fall into the four categories outlined in Table 2. Comparing rules and reasons provided in Table 1 and 2, it appears that students based their selections on different criteria. Whereas, the majority of rules for previous interactions were based on social or random factors, after studying the social network graph, students cited what could be understood as more cognitive or informational factors as reasons for who to talk to.

Table 2: Reasons given for who students wanted to talk to after reading the graph.

Reason	Frequency
Want to understand why their ratings are different	7
Want to convince the person	5
No reason given	2
Want to be convinced by the person	1

Discussion

The pattern of choosing friends, also known as homophily, is a particularly robust finding in studies of social networks of adolescents and has been shown to produce detrimental effects, for example, with respect to harmful substance use (Ennet et al., 2006), emotional and behavior disorders (Farmer & Hollowell, 1994), and academic effort and choice (Frank et al., 2005). Frank (1999) discusses two fundamental principles of social psychology that link interactions of actors in networks to their decisions or rationales for choice. The first principle describes choices being made based on the need to think and behave like others around them. The second principle describes choices based on informational or knowledge needs. Others have discussed similar dual categories of decision-making processes that compare socially-oriented selection pressures to cognitively or conceptually-oriented selection pressures such as content vs. non-content bias (Gil-White, 2004); practical problem-solving vs. norm adoption and identity membership (Castlefranchi, 2001); and memetic or copying mechanisms vs. non-memetic mechanisms (Dennett, 1995). Stanovich (2004) states that such processes can be described in terms of reflective vs. non-reflective selection. In any case, the implications for educational contexts are clear in that the latter of the dichotomies ought to be the primary focus for school and learning in order to challenge the potentially detrimental effects that social mechanisms can have on students. This study aimed at investigating what participatory simulations coupled with social network analyses could reveal about students' decision-making processes and how students use information from social network graphs to make decisions. It has been demonstrated that information contained within social network graphs can be used by teachers to trigger more cognitively-oriented selection rules or strategies. As previously noted, further analyses are yet to be completed with the content of student rationales and discussions produced by the *Discussion Game* in which further support for the use of participatory simulations and social network analyses in educational domains is expected.

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The disembodied act: Copresence and indexical symmetry in computer-mediated communication

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Abstract: CSCL has recently begun to consider how shared understanding is achieved in computer-mediated interactional environments. In this paper, we explore how actors produce and maintain indexical symmetry and reciprocity of perspectives in online chat by establishing reciprocal fields of copresence. We use ethnomethodologically informed analysis to describe the interactional methods by which actors establish indexical symmetry and reciprocal fields of copresence.

Introduction

Web-based technologies support fundamental features of social interaction. Suitable platforms now exist that exploit the production of reciprocal perspectives through the performance of disembodied actions. These technologies offer different affordances for the display of actions, the practices of reference and representation, and the achievement and maintenance of presence, copresence and indexical symmetry which account for the significant differences between interactions based on disembodied action and those based on embodied action.

Social 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. Social interaction requires more than reciprocal contact, it requires a reciprocity of perspectives. 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." This reciprocity of perspectives establishes a sense of copresence in which the experiences and perceptions of the actors in a scene become practically available to each other. In this research, we demonstrate how shared understanding and group cognition (Stahl, 2006) are achieved through the coordinated exchange of postings, the display of whiteboard objects and the indexical symmetries these exchanges and postings both display and achieve.

Analysis

We examined recorded logs from student interactions using the VMT Chat System. The data consist of time-stamped chat logs and whiteboard displays of math problem solving sessions among middle school students. The chats were sponsored and conducted by the Math Forum of Drexel University as part of its participation in the Virtual Math Teams (VMT) research project, an NSF funded project..

One of the features of systems that use chat and virtual whiteboards is that actors are never actually present to others in an embodied sense. Their presence is established and inferred from actions originating from their "node" that change the system in ways that are observable to others. However, presence is not sufficient to achieve social interaction. Copresence is a condition of and for social interaction. According to Zhao, "Copresence as mode of being with others is a form of human colocation in which individuals become "accessible, available, and subject to one another" (Goffman, 1963, p. 22). More specifically, it is a set of spatio-temporal conditions in which instant two-way interactions can take place. *Instant* human interaction refers to real-time or near real-time human communication, which excludes diachronic exchanges like postal correspondence, and *two-way* human interaction refers to reciprocal or feedback-based human communication…. Copresence in this sense is thus a form of human colocation in space-time that allows for instantaneous and reciprocal human contact" (Zhao, 2003, p. 446).

Chat properly consists of a series of labeled, time-stamped text postings that are treated as accountably authored actions. These actions are 1) prospectively implicative with respect to the appearance of possible next authored postings and 2) retrospectively implicative with respect to the intelligibility of prior postings. The reciprocal nature of these postings demonstrates participant's perspectives in ways that allow for mutual orientation. There is, built into them, the assumption that a reader will be able to occupy to some degree the perspective of the author of the posted text.

As an example, the text posting, "hi." is readable as an authored social action, a greeting that calls on others to respond. It is a textual artifact the sense of which is determined by the recipients' work of reading (Livingston, 1995). In online chats, *the actors' work of posting and reading text messages is how they organize, constitute and participate in chats*(1). Readers are capable of assuming the perspective that this posting represents and thus know how to read it as a greeting. It is the recognizable design of the postings achieved through the work of reading in the chat environment that allows recipients to regard this posting as a social action. That the recipients recognize this posting as a social action is evidenced by subsequent postings that serve as in-kind responses, thus displaying that the initial posting was recognizable and treated as a greeting.

Each posting is assigned "authorship" by the system based on login information provided to the system. System-documented authorship is part of the way that the system itself facilitates and organizes the presentation of postings as the copresence of the author and recipients. Furthermore, each posting is displayed sequentially in a stream of postings with an appropriate time stamp. The appearance of sequential postings allows for recipients to treat the appearance of postings as an orderly affair, making the "readability" of a posting unproblematic(2). Each posting is available as both authored, sequenced and addressed, thus serving as a method of displaying a mutual orientation to other actors, since postings are texts that others are expected to read and to which one, some or any may respond.

The intelligibility of chat postings occasionally requires that readers refer to and inspect the virtual whiteboard. Consider the following chat postings, "How long is that line?" followed by "Line AB." No other markers or referential indicators are used. The intelligibility of these posts relies on the presumption that there actually are inspectable referents for recipients to inspect and makes relevant recipients' inspection of the virtual whiteboard for the referent to which these indexical expressions refer.

The achievement and management of indexical symmetry includes matters conventionally considered conceptual or cognitive in nature. Various conceptual objects are represented in the chat and on the virtual whiteboard as relevant matters about which inquiry can be made, for which there are shared-in-common practices by which reference can be made and about which mutually relevant responses can be produced. Consider the following postings:

"Im (8:35:12 PM EDT): How long is that line?"
"Im (8:35:21 PM EDT): Line AB".
"F (8:35:25 PM EDT): 10"

This invokes an organization of conceptual features, such as the various properties (length, "How long…") of recognizable and identifiable geometric objects ("that line," "Line AB"). The response to the query is "10". This is produced without embellishment or elaboration, affirming that the referenced feature (length) of the conceptual object (the line) is both intelligible and practically describable, and that such a description can properly consist of a numerical representation. Thus the response, "10," is presented as and is seen to be a candidate value for the line's length.

The production and maintenance of indexical symmetry in VMT chat with respect to conceptual objects and their features thus involves:

- displaying authored text postings for other participants to read,
- displaying conceptual objects using textual references, graphical displays, deictic references, etc., for others to inspect
- providing participants with ways of locating and identifying displayed conceptual objects, and
- using these text postings and object displays according to recognized and proper practices of use that demonstrate that actors are copresent and share a mutual and symmetric orientation to each other and the referential objects and resources of their interaction.

Discussion

Indexical symmetry is the ground upon which shared understandings are established and maintained. In face-to-face interaction, indexical symmetry is achieved, demonstrated and maintained through the embodied actions of indexical reference. These actions, which are the observable and reportable organization of actors' participation in their interaction, constitute their shared understanding. Shared understanding thus is an interactional matter. In chat, the procedures by which users "use" the system, and the ways that the chat system responds to that use, is treated by users as interaction. This kind of interaction is distinguished from other forms of interaction by virtue of the fact that actors are not actually present to each other, at least not in any embodied sense. The disembodied nature of chat interaction presents challenges and opportunities to users (Garcia and Jacobs 1999).

Part of the practical achievement of interaction therefore involves establishing and maintaining presence, copresence and mutually sustainable recognition of features of their interactional space. In other words, actors must be recognizable as actors in the scene. They must be recognized as actors in the ways they participate, in ways that are intelligible to themselves, other actors in the scene, in ways that display that they are participants. While Hanks (1992, 1996, 2000), Goodwin (2000, 2003), Hindmarsh and Heath (2000) and others have explored these issues in face-to-face interactions, we propose to examine these issues in an online environment in which actors interact by posting text messages to a chat system and posting objects and text documents to a linked virtual whiteboard.

Endnotes

(1) According to Livingston (1995), "The work of reading is the work of finding the organization of that work that a text describes. The contextual clues in a text offer the grounds, from within the active participatory work of reading, for finding how those clues provide an adequate account of how the text should be read." (p. 14).

(2) Readability is different from intelligibility. While chat postings may have identical time stamps, there is no possibility of "overlap" in any conventional face-to-face conversational sense since the system automatically assures the sequential display of all postings.

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Information as a Social Achievement: Collaborative Information Behavior in CSCL

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Abstract: In computer-supported collaborative learning (CSCL) environments, learners in problem solving contexts constantly engage in information seeking, information sharing, and information use. However, these activities have not been well investigated in CSCL research. We have studied information behavior of small groups of middle school students engaged in online math problem solving. More specifically, we examined how participants negotiate and co-construct their information needs, how they seek information, and how they make sense of discovered information. We argue that for learners in a CSCL environment, information is essentially a social achievement that emerges through the interactions of the group. Information only becomes *information* for participants when it is interactionally constructed to be meaningful and intelligible in their local situation. Analyzing learners' information behavior from such an interactional perspective can help us understand their *practices* of doing collaboration and learning. This has significant implications for designing CSCL environments and information resources to support small groups' information behavior and collaborative learning.

Keywords: CSCL, information behavior, conversation analysis, meaning making

Introduction

In his keynote talk at CSCL 2002, Koschmann (2002) defined the central concern of the CSCL field as "meaning and practices of meaning making in the context of joint activity and the ways in which these practices are mediated through designed artifacts". People often interact with information resources to learn. We experience intentional learning in schools, libraries, and other contexts. We also are engaged in a constant process of informal learning in our everyday life in order to make sense of what is around us, to solve a task or a problem, to make decisions, and so forth. Information seeking, processing, creating, and using are central activities in such a sense-making process in order to bridge the gap of understanding. In this paper, we argue that these activities of information practices are essential components of the *practices* of meaning making and learning for learners in collaborative environments, and thus need closer examination and understanding.

Information behavior, "the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking, and information use" (Wilson, 2000, p. 49), has been one of the central topics of information science. A large quantity of research has been done but most of them tend to focus on individuals. Information behavior has been of interest to CSCL researchers even though information practices in the context of collaboration are still relatively less studied thus not well understood. In the study presented in this paper, we have observed interactions of small groups of middle school students engaged in solving a mathematical problem collaboratively in virtual environments. We have examined how students identify and construct their information needs collaboratively, how they go about finding the information, and how informational artifacts are produced and recognized as meaningful and useful information for them.

This study is situated in a larger research agenda of the Virtual Math Teams (VMT) research project where researchers investigate the innovative use of online collaborative environments to support effective K-12 mathematics learning. At VMT, students are invited to participate in about one-hour-long chat sessions in online environments where they discuss and solve a math problem in small groups. The chat is recorded for analysis. We have applied an ethnomethodologically-informed approach that combines aspects of conversation analysis (Sacks, 1992) and ethnomethodology (Garfinkel, 1967) to analyze information practices of participants in small groups (Stahl, 2006b). We argue that information is a social achievement, that is, information is not given, but is a kind of status accorded various situated, locally designed and produced artifacts. This status is not a feature of the artifact but is produced as an interactional social achievement. Seeing information from such an interactional perspective can help us understand participants' *practices* of doing collaboration and learning.

Data Analysis

In this section, we show the analysis of one excerpt of interactional data on how participants construct information needs and how an informational artifact is produced as meaningful information for them. The following 7 minute long except (Table 1) is from a VMT chat session during which three participants (REA, PIN, MCP) are working on a geometry problem as presented in figure 1 through an AOL chat program. A moderator is there to get them started by first greeting them, presenting the problem, and explaining that the task for them is to share their ideas and collaborate on solving the problem. They are also asked to make sure everyone understands if they think the problem gets solved. It is about half way through a one hour and twenty minute session. Before the conversation gets to this point, REA and PIN have already engaged in active discussion. One of them created a picture as shown in Figure 2 and sent it to the moderator. It was made available to the group through a website, which they have been referring to in this excerpt of their interaction.

Table 1: An excerpt from a VMT chat session

Line#	*Handle*	*Posting*	*Time*	*Delay*
120	REA	Are u there PIN	8:48:08	0:00:17
121	PIN	ya im here	8:48:29	0:00:21
122	REA	checking	8:48:37	0:00:08
123	REA	u stuck cause i am:-(	8:49:07	0:00:30
124	PIN	well angle CED is congruent to angle B	8:49:56	0:00:49
125	PIN	if that helps	8:50:06	0:00:10
126	REA	It helps	8:50:48	0:00:42
127	REA	but i already estlabished that	8:51:15	0:00:27
128	PIN	im stuck	8:51:36	0:00:21
129	MCP	What's known?	8:51:42	0:00:06
130	MCP	BE:EC = 3:5, right?	8:52:05	0:00:23
131	REA	how did you get that	8:52:42	0:00:37
132	PIN	how did u get that	8:52:43	0:00:01
133	PIN	lol	8:52:46	0:00:03
134	MCP	Tri ABC similar to DEC	8:53:10	0:00:24
135	PIN	ya we got that	8:53:19	0:00:09
136	MCP	AB:DE = 8:5, right?	8:53:30	0:00:11
137	REA	We know that	8:53:33	0:00:03
138	PIN	ya	8:53:35	0:00:02
139	MCP	So BC:EC=8:5	8:53:51	0:00:16
140	REA	ya	8:54:11	0:00:20
141	MCP	That 8 breaks down 3 for BE, 5 for EC	8:54:23	0:00:12
142	REA	We might have to use law of sines	8:54:38	0:00:15
143	PIN	havent learned that yet	8:54:50	0:00:12
144	PIN	whats it say	8:55:04	0:00:14
145	MCP	Sine A / a = Sine B / b = Sine C / c	8:55:15	0:00:11

Finding CE - posted February 16, 2004
Given the following situation:
- Side AB of triangle ABC has a length of 8 inches.
- Line DEF is drawn parallel to AB so that D is on segment AC and E is on segment BC.
- Line AE extended bisects angle FEC.
- DE has a length of 5 inches.
What's the length of CE?

Figure 1. Problem: Finding CE

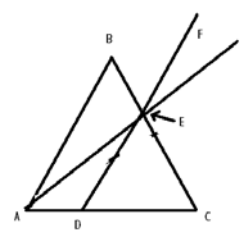

Figure 2. The drawing

REA's posting at line 123 is read as a question directed to PIN asking about PIN's status on solving the problem: "(are) *you stuck* (?)". It also establishes REA's own position as "being stuck". This inquiry is taken up by PIN as a request for information that could possibly help him getting "unstuck". PIN responds with providing some information that he possibly has discovered from the problem description ("*angle CED is congruent to angle B*"). This offering of information is followed by "*if that helps*", calling for work of assessment of its usefulness in terms of solving the problem, which is ratified by REA, followed by the statement that the information is not new ("*but I already established that*"). At this point, a request for information is made; an attempt of providing the information is assessed as "useful" but not new; therefore the earlier request is still open but revised as a request for something new. PIN articulates he cannot be of any help to take up the request, which opens up an opportunity for other participants to bring in new, potentially "useful" information.

Right at this moment, MCP joins this line of conversation by asking a question "What's known?". One of the features of this query is that it is calling for recipients to consider a set of resources that can be shared. It serves to preface what will follow as information action, organizing action in relation to others and to available resources in ways that provide for subsequent postings to be seen as informative. MCP takes over the call himself by proposing a math proportional equation. This proposition is phrased as a question to solicit assessment from the group. This proposal is responded to by each of the two participants by directing an inquiry for further information, that is, a request for MCP to produce some elaboration or account for what he just provided as "known" fact. We see that three co-present participants displayed different levels of understanding on what is known at this point. This discrepancy needs to be resolved to bring the group into sync in order for them to proceed with collaborative problem solving, that is, to build a common ground for their subsequent interactions. In this excerpt, MCP is called upon to elaborate on his offering and share what he knows with the rest of the group. This is what we will see shortly in the following interactional moves. We will also see that "information sharing" here is not simply transferring a piece of information as a bounded object. Rather, participants do the work of building understanding of the *information* in their situated locus. It is the work they do that makes a potentially informative artifact meaningful and intelligible for them.

MCP takes up this request and starts to present to the group how that "known" fact is derived by what is given in the problem step by step. This expository work of MCP as an effort of producing an account of the information is led in an organized way of presenting base facts and what is being derived from them. Each step is aligned with agreement or acknowledgement from the other two participants. In line 141, by concluding "That 8 breaks down 3 for BE, 5 for EC", MCP completes the process of presenting a proof. MCP's last posting as part of the offered explanation doesn't get a response. The fact that this thread of expository work stops here marks the conclusion of the work of producing an account of the "known" fact "BE:EC = 3:5" and making meaning of this account by other participants. This also signals the transition between threads of conversation and opens the interactional space up possibly for a new incoming proposal. 15 seconds after the preceding posting, which is a noticeable gap in a live chat, REA makes a proposal that suggests the possibility of using "law of sines" as a strategy to proceed on tackling the problem. By stating he hasn't learned that yet, PIN positions himself as an inquirer seeking information. This information inquiry is responded to by MCP who provides the equations of law of sines.

Discussion

When students are working on a math problem together, they often need to find information that they think is useful for solving the problem. Usually the process starts with identifying what is known and what is needed. As demonstrated in the preceding analysis, information needs are negotiated and constructed by the group. When an information need is specified and posed, there are different ways the subsequent interaction unfolds. In this particular case, proposals on what information might be useful are provided. A proposal is either evaluated by participants on its usefulness or initiates a request for more information to elaborate on it. The latter constitutes the process of participants making meaning of the information being provided. The information provider is called upon on producing an account of it, which is achieved interactionally with calling for and getting assessment or acknowledgement. Only through such interactional work is the information artifact made meaningful for the participants in the local context, thus becoming real *information* for them. Information is not a predefined object with fixed boundaries but emerges as a product of the social interaction. In this exemplary case, we showed our analysis on how "BE:EC=3:5" as an information artifact is produced as meaningful information for the participants. Most online information resources are organized in a way that information is treated as an object with fixed boundaries. It is questionable how such resources can help learners find what they need and support their learning experiences and collaboration. Analyzing group's information behavior and seeing information from an interactional and social perspective can help information resource design, for example, how resources can be organized to provide multiple access points to learners at different levels and how social aspects can be brought into the design of digital libraries. We have noticed that most participants treat the group as a primary resource for seeking information although some of them also actively use online resources such as Google, the Math Forum digital libraries, wikipedia, etc. How to integrate various resources in to CSCL environments to support learners' needs is another question being put on the research agenda for the community.

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Mice, Minds, and Society

Workshops

New authoring frameworks for integrating collaborative learning technologies

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Abstract: This workshop is intended for CSCL researchers and/or their technologists who are interested in designing and then actually creating rich, interactive learning materials in a technology-enhanced environment. The workshop will present the work of two complementary approaches to the design of environments for collaborative, productive and open ended learning, such as collaborative inquiry learning and learning by design. Participants bring in their own issues and work on the design of learning environments in a hands-on experience.

Theme and goals

This workshop offers participants the chance for hands-on experience with two recent authoring frameworks for technology-enhanced CSCL activities. We will describe how to adopt these environments as sustainable research platforms, and discuss the vision of a community of developers. We address the issues of interoperability, re-use, open source and open content, as well as recent trends toward standardization (e.g., SCORM or IMS/LD). We invite participants to bring with them: A description of a CSCL activity that they would like to develop; a specific CSCL tool or technology that they would like to integrate within a larger framework; an idea for a new tool or feature that they would like to create; research questions they would like to address. We will discuss key issues and present demonstrations in the morning, followed by direct hands-on work by individual participants, in consultation with workshop leaders.

The leaders of this workshop have a wealth of experience in the development of technology frameworks for CSCL activities. Jim Slotta (2000, 2004) led the design of the WISE learning environment (http://wise.berkeley.edu) - a Web-based system that allows researchers to develop interactive inquiry projects, delivers the content to students, collects all data, and supports teachers as they implement the materials in their classrooms. Numerous research labs now use WISE as a research platform for the development and delivery of experimental materials. Wouter Van Joolingen and his colleagues (van Joolingen & de Jong, 2003; van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005) have developed Simquest (http://www.simquest.nl), which guides learners through a structured inquiry process, and more recently, Co-Lab (Collaborative Laboratories - http://www.co-lab.nl), which allows learners to collaboratively set up a study of the climate in a greenhouse, design experiments, process the data from these experiments, develop models and theories, and report about their work. Turadg Aleahmad (Slotta & Aleahmad, in press) has led the design of the new Scalable Architecture for Interactive Learning (SAIL, http://sail.sourceforge.net), a framework for developing pedagogical software, and Pas, an application suite for collaborative inquiry learning. We will demonstrate our latest innovations, discuss the most pressing topics related to technology frameworks, and consult with participants to help them take forward strides in developing their own materials or make decisions about research platforms.

This new generation of open software allows a greater degree of innovation and enables a wider range of pedagogical scenarios (Slotta & Aleahmad, in press). SAIL is Java component framework that enabled the rapid development of Pas, which like WISE includes everything required for researchers to adopt as a stand alone research platform. All SAIL-based objects can be shared amongst any SAIL-based platform, allowing the development of an exchange community. The hope is that this will encourage a community of open source development, enabling rapid evolution and exchange amongst researchers. Another framework is CIEL: Collaborative Inquiry and Experiential Learning (http://www.cielproject.eu), which enables collaborative real time environments to interoperate with other learning technologies.

These resources are available to CSCL researchers right now. Indeed, most labs that were using the WISE system are now adopting their own SAIL-based platforms, and will go forward with separate but interoperable systems. CIEL has enabled the integration of the Co-Lab software with a suite of tools called Cool Modes developed by researchers in Duisburg-Essen University (Pinkwart, 2003; Pinkwart, Hoppe, Bollen, & Fuhlrott, 2002). The goal of this workshop is to offer such resources to the wider community, discuss a range of issues including interoperability, scalability and sustainability, and engage participants in hands on design and authoring activities.

Outcomes and contributions

- In advance of the workshop, each participant will complete a wiki template concerning: their topic of research; specific scenarios concerning the kinds of learning materials or tools they would like to develop; their questions with regard to interoperability; their personal goals for the workshop.
- In advance of the workshop, these participant submissions will by synthesis by the leaders into a small number of discussion categories for the workshop. This and the discussion at the workshop will remain in the wiki for future reference and discussion.
- We will offer each participant open access to all the technology, including them in a community (ENCORE, http://www.encorewiki.org) that will provide ongoing support. We hope for participants who have the intention of adopting these systems, and will work with them to develop a clear understanding of their next steps, as well as a sense of active membership in a community of peers.
- For each participant, the workshop will contribute distinct, individuated progress in their thinking about the design, development and implementation of CSCL activities using these new frameworks.

Format

- Designed for 5-20 participants.
- In the morning, we will have introductions, demos and discussion. One goal of discussion is to address common issues relating to technology frameworks (e.g., standards, re-use, learning content management, etc). Another is to develop shared views on the architectures for collaborative inquiry learning, expressed in a shared collection/classification of learning objects and tools. We would also review the ideas from the pre-workshop wiki, examining the scenarios of inquiry learning, etc.
- In the afternoon there will be hands-on authoring, design, and question and answer consultation, giving each participant a direct experience of progress, including "next steps" for their participation.
- The workshop will conclude with a synthesis discussion and presentation of ENCORE.

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Acknowledgements

This work was supported in part by Graduate Training Grant awarded to Carnegie Mellon University by the Department of Education (# R305B040063).

The Third Metaphor of Learning

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Abstract: Sfard (1999) distinguished two different metaphors for learning. The metaphor of acquisition implies that learning is an individual process, gaining possession over some commodity (knowledge, concepts), by transfer and internalization. The metaphor of participation implies that learning is the process of initiation and enculturation of newcomers in a community of practice. Paavola, Lipponen and Hakkarainen (2004) claim that neither metaphor captures the processes of knowledge creation and advancement, which occur when new ideas are developed during some forms of collaborative activities. To overcome this omission, they proposed a third metaphor: knowledge creation. In this preconference event we address the question what is specific about CSCL within a knowledge creation metaphor.

Introduction

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Outline of the program

The program includes 5 presentations (20 min, incl. short questions), in which the speakers present a case and elaborate its findings in terms of theory and practice of knowledge creation. After that, two discussants make up the balance in favor of or against the feasibility of a third metaphor for research and practice of CSCL (15 min each). The discussants end their evaluation with one or two questions for the audience and speakers to debate (30 min). The outline of the program (3 hours + short break) looks as follows:

Dialogues and Trialogues as a Basis for Collaborative Learning

Sami Paavola & Kai Hakkarainen (Centre for Research on Networked Learning and Knowledge Building, University of Helsinki)

Our aim is to compare KP-Lab's "trialogic" approach to dialogic approaches. It has been maintained that *dialogic* theory of learning forms an integrative basis for learning and especially for CSCL (e.g. Koschmann 1999, Wegerif 2006). We describe various ways of interpreting dialogic approaches and how they are related to Sfard's participation metaphor of learning. We maintain, however, that in addition to these and in accordance with the knowledge-creation metaphor of learning, a *trialogic* approach is needed which concentrates on long-term efforts at developing some concrete objects - material or conceptual artifacts - collaboratively (Paavola & Hakkarainen 2005). Successful examples of trialogic activities are wikipedia and open source communities where the wikipedia pages or a code (as shared objects) are developed. We shall present ways of interpreting and developing so-called *progressive inquiry model* towards trialogic approach. Enyedy & Hoadley (2006) has identified two main categories common in CSCL and in computer based media in general: *information* and *communication* media with monologues and dialogues as respective social activities. They search a "middle space" with these which would provide connections between them. We agree with this aim but by searching trialogic tools with related knowledge practices and models in educational contexts.

Design-based research in a small software company: Studying the transition from old to new knowledge practices

Anders Mørch, Anne Moen, Kathrine Nygård, Sten Ludvigsen (InterMedia, University of Oslo, Norway)

The aim of the KIKK (Knowledge Management for Internal Communication and Customer support) case is to study emerging knowledge practices, using design-based research methodology: 1) defining an empirical case in a professional organization, 2) iterative development of innovative technology, and 3) application of KP-Lab theory to the design and analysis. The professional organization is a small software company, which produces project planning software and services for the Norwegian oil and gas industry. To support growth and transition to new markets the company decided to introduce a CRM-based web-portal to improve existing routines for customer relations and internal communication. We are in the midst of studying the effects of this intervention. The pedagogical and technological design is a collaborative effort between researchers and members of the company (users and developers). The design is informed by KP-Lab principles. Technology development is a combination of reusing open source systems and development frameworks, developing new tools and integrating them with existing tools tailored for the purpose. The new tools will be evaluated using KP-Lab theory-informed heuristics.

Analyzing Design of Learning Instrumentalities – Questions to "Trialogical" Approach

Hanna Toiviainen and Yrjö Engeström (Center for Activity Theory and Developmental Work Research, University of Helsinki)

Designing new learning instrumentalities by a cross-disciplinary design team requires long-standing collaboration and co-configuration, in which each partner will learn from others and move towards a collectively created object. Based on our recent analysis of an empirical case study in the frames of the KP-Lab, this presentation points to the importance of creating and using intermediate tools to make co-configuration design possible. Such intermediate tools, or boundary objects, need to be collaboratively created, contested and reconstructed in use. We address three questions to the "trialogical" approach: 1) Emphasizing objects and artifacts in the learning interaction, does the trialogical approach provide an analytical distinction between the object and tools? This is crucial in the ICT-rich activities in which tools easily become quasi-objects. 2) Compared to the dialogical approach, does the trialogical approach adhere to the situational interactionism in which the partners of dialogue are embedded, or does it anchor the community to the institutions and organizations? In the activity-theoretical terms, the analysis of rules and division of labour is important. 3) The first two questions lead to the question of history and historicity: what is their place in the trialogical learning approach?

Analysis of a trialogical activity by collaborative social scientists: was new knowledge created?

Jerry Andriessen, Patrick Sins, Crina Damsa (Utrecht University)

The KP-Lab project examines trialogical activities in school and business contexts. However, in this contribution we describe an effort by researchers themselves to engage in knowledge creation. A group of researchers from the KP-Lab community tries to establish criteria for analyzing dialogues in order to arrive at (some) common descriptors to study knowledge creation by the participating research teams. This is a real challenge, because researchers have different backgrounds and theoretical views on dialogues and their value. A scenario is created in which researchers briefly state (and make public) their ideas on the analysis of dialogues, then each team analyses the same collaborative dialogue in their own way, and make the analysis public. These collaborative (oral) activities are registered and analyzed. Then, a virtual meeting is held, between researchers, whereby the different analyses of the common dialogue are discussed. The goal of these activities is to agree on criteria for knowledge creation in dialogues, thereby deepening theoretical and practical ideas about knowledge creation by social scientists. The analysis of these collaborative activities is reported in this contribution.

Analyzing learning according to the third metaphor: what does it contribute?

Baruch Schwarz (Hebrew University of Jerusalem).

In this contribution, a same set of data from a collaborative learning protocol meeting trialogical learning standards, is analyzed according to the principles governing the three different metaphors. An attempt is being made to evaluate the outcome of the analysis in terms of each metaphor.

Discussion: Anna Sfard (confirmed), Tim Koschmann (confirmed)

The Use of CSCL Design Patterns as a Vehicle for Effective & Efficient Learning Designs: Linking Patterns to Authentic Educational Case Studies

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Abstract: The scope of this workshop is to identify the way of linking design patterns with authentic cases and thus towards a better elicitation process for patterns of various kinds, e.g. system oriented patterns, learning flow design patterns, subject oriented patterns. Design patterns are general repeatable well justified solutions to a commonly-occurring learning design problem. This workshop can be regarded as a live multidisciplinary forum where attendants will exchange their know-how and ideas on how to take benefit of sharing and reusing design experiences and theoretical results in different fields, and how to apply design patterns as a way for creating usable and useful interactive learning Environments more effectively.

Workshop Rationale

Designing effective computer supported collaborative learning (CSCL) environments in an efficient affordable way is a demanding task, which requires creativity and a significant amount of expertise. Thus, people new to the CSCL learning design need advice from experts, experienced peers and users so as to avoid "re-inventing the wheel". Experience is often shared informally, in the everyday language of teaching practice, or through published research and evaluation studies, or even through sets of action-oriented guidelines. Another powerful medium for sharing experience is the use of design patterns.

A design pattern can be defined as "… a named nugget of insight that conveys the essence of a proven solution to a recurring problem within a certain context" [Appleton 2000]. In its simplest form, a design pattern is a recurring design problem associated to a design solution that has been proved to be effective within a specific situation [Alexander, 1979]. It provides a structure for integrating the analysis and the solution of a problem, in a way that is sensitive to context, is informed by theory and evidence, and is usable with a minimum degree of customization. Recently various publications about CSCL design patterns have appeared [e.g. Georgiakakis & Retalis, 2006; Goodyear et al., 2004; TELL, 2005; Hernández, et al., 2006; Schümmer & Lukosch, 2007]. A frequent criticism to design patterns is the informality of pattern descriptions, and the lack of a systematic framework to define, analyze, organize and evaluate them. This is largely due to the intrinsically empirical nature of patterns and to the difficulty of identifying the proper perspective, level of abstraction, and granularity for shaping a design problem and for describing its solutions.

Thus, research and development teams are working on following topics about CSCL design patterns: i) the development of a framework for embracing the diversity of the types-kinds of published CSCL design patterns, ii) their quality and maturity and their linkage to authentic learning case studies, iii) the way of eliciting design patterns and iv) the way of effectively utilizing them within the instructional design process.

The ultimate scope of this workshop is to identify the way of linking design patterns with authentic cases. As an effect, we could identify better elicitation processes for various kinds patterns (e.g. system oriented patterns, learning flow design patterns, subject oriented patterns), as well as new design pattern based instructional design processes.

In this workshop, the targeted audience consists of design patterns authors and users (i.e., educators and/or system designers) who think of CSCL design patterns as mappings from the instructional requirements "problem space" (learner characteristics, instructional needs, learning goals, motivations, situations of use, …) to the design CSCL "solution space". We regard this workshop as a live multidisciplinary forum where attendants will exchange their know-how and ideas on how to take benefit of sharing and reusing design experiences, and how to apply design patterns for creating usable and effective interactive learning environments.

This workshop is in line with previous similar workshops on CSCL design patterns (CSCL 2003, EDMEDIA 2004, ACM SAC 04), learning designs (ICALT 2006) or CSCL scripts (CSCL 2005, 2007 CSCL Alpine Rendezvous). While these workshops have been focusing on collecting and structuring patterns and pattern languages, we now focus on the applicability of patterns in the CSCL design process always in relationship to user needs, both from a general perspective and in specific application domains, also adopting a multidisciplinary approach. This workshop is also tightly coupled to R&D projects that deal with design patterns in e-learning and CSCL in particular, such as the European projects ELEN [http://www.tisip.no/ELEN], TELL project [http://cosy.ted.unipi.gr/TELL], Kaleidoscope Network of Excellence [http://lp.noe-kaleidoscope.org/] or ones funded by US agencies, such as the PADI project [http://padi.sri.com/].

Workshop Topics

The main topics of this workshop will be related to:

- Case studies or experiences from the use of CSCL design patterns as a design vehicle
- User centered design methods using patterns
- Methods for discovery/mining of CSCL design patterns
- Cognitive foundations for CSCL design patterns
- CSCL design patterns for specific user needs and "contexts" (i.e., devices or situations of use)

This workshop does not aim at collecting just a set of design patterns, which might happen as a side effect. Its aim is to start building a multidisciplinary conceptual framework where current and future patterns can be defined and organized more rigorously, and used more systematically for analyzing design trade-offs. The framework will act as a vehicle for guiding development activities by professionals and end-users, helping them to translate user requirements to design decisions more efficiently and linking them to authentic educational cases. Patterns that will be illustrated by authentic cases would, also, provide more clues to potential users on how to use them.

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Networked Learning and CSCL

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Abstract: Networked learning focuses on the connections between learners, learners and tutors and between learners and the resources they make use of in their learning. This approach to learning suggests *a relational view* in which learning takes place in relation to others and in relation to learning resources. Networked Learning is a distinct research area and the workshop explores five theoretical strands that contribute to networked learning and investigates the relationships between networked learning and CSCL.

Networked Learning

Networked learning is an approach to learning that suggests *a relational view* in which learning takes place in relation to others and also in relation to an array of learning resources. Networked learning has become a recognised research area that has developed its own series of international conferences and publications. The field is not clearly distinguished from CSCL and there are a number of publications from this tradition in the International Journal of Computer-Supported Collaborative Learning (ijCSCL) and the Kluwer CSCL book series (for example Goodyear et al. 2004). The workshop arises from the work of two European research networks and will represent some of the work undertaken in one Kaleidoscope (www.noe-kaleidoscope.org) European Research Team *Conditions for Productive Learning in Networked Learning Environments*. We take as a starting point the definition that networked learning is:

> learning in which information and communication technology (C&IT) is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources (Goodyear et al. 2004 p1).

The important element of this definition is the idea of *connections* as connection does not privilege any particular kind of relationship and allows for the strong connections of community and collaboration without excluding the possibility of patterns formed by weaker links or a combination of weak and strong links

Theoretical Roots

The definition of networked learning provided above is taken as a starting point to explore five theoretical strands and the key ideas that arise from these sources, all of which have contributed to an interest in applying the metaphor of networks to learning. The theoretical strands include:

- Theories of network society and networked individualism (Castells 2000 and Wellman 2003)

Castells' work concerning the networked society is well known and suggests that the move in education towards e-learning is connected to a broad set of social changes characterised as the network society. One of the key ideas drawn on by Castells is the idea of networked individualism, first developed by Barry Wellman. Networked individualism suggests that the pattern of social relations emerging around the use of digital networks is one in which individualism is reconfigured through new patterns of social relationships dependant on the network.

- Theories of networked learning (Goodyear et al 2004; Hodgson and Watland; McConnell 2000)

The idea of networked learning has more than one source but perhaps the most persistent and developed has been the work conducted at Lancaster University in the UK and the related Networked Learning conference series supported by both Lancaster and Sheffield University. The relationship to CSCL has not been clearified and one of the key individuals connected to the Networked Learning conference series is David McConnell who is the author of the book *Implementing Computer Supported Cooperative Learning* (1994, 2000 2nd Edition).

- Theories of networks related to mathematics (Barabasi 2002)

In recent years there has been a growing interest in mathematics in network theory and how it can be applied to a wide range of phenomena including the Internet and Web. Some of this work is relevant to learning in that it points to commonly repeated network patterns, such as scale free networks, that have development over time and definite forms of organisation.

- Social Network Analysis (Wellman and Berkowitz 1988; Freeman 2004)

For a considerable time interest in social networks has developed as a strand of social science. This research has generated a considerable literature and mature techniques for research. The structural approach adopted by SNA has come under criticism for the way in which networks can be mapped using sophisticated software that may generate apparently secure findings whilst ignoring some fundamental aspects of the relationships the method claims to have revealed. The approach has generated a number of key insights including the notion of the 'strength of weak ties' (Grannoveter 1973), a notion developed outside of the context of digital networks but one that is highly suggestive when applied to the Internet and Web.

- Actor Network Theory (Callon and Latour 1992; Law 1992)

Actor Network Theory is a mature approach that has developed a number of useful theoretical ideas that inform current thinking about technology use and social form. One of the key ideas derived from actor network theory is the idea of an actant, a non-human agency in which things can act in the social world. Actor network theory has also given rise to a consideration of weaknesses in the original formulations and popularisations of the original stances taken by ANT. Points of interest are the concern the problem of fluids for ANT and the way in which network flows may not be properly captured.

A consideration of these strands and what they can contribute to research will lead on to a discussion about the ways in which networked learning relates to CSCL. The idea of networked individualism will be explored in the context of common pedagogic preferences for community, cooperation and collaboration, and the idea of networked learning will be explored in the context of social and situated views of learning in particular legitimate peripheral participation and communities of practice.

The aim of the workshop will be that participants will have a clear conception of networked learning and its contribution to understanding learning mediated by digital and networked technologies. It is hoped that those who participate will also develop their own understandings of the relationships between networked learning and the CSCL research tradition.

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Wiki Research: Knowledge Advancement and Design

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The goal of this workshop is to identify emerging research issues in the study of relationships between knowledge advancement and wiki technology. The rationale for this goal is found in an increasing interest in collective knowledge building and creation and the need to take on complex challenges or problems that would typically be beyond the capacity of the individual. Wikis, with their collaborative and collective features, are an interesting 'social software' that seems to hold potential for supporting collective knowledge building activities inside, outside and across institutional settings.

There are two interrelated themes that we consider particularly relevant for wiki research, namely design and knowledge advancement. Research on knowledge advancement in relation to wiki technology explores the educational use of wikis in different learning settings, and how such use challenges established practices, tasks, and concepts of collaborative knowledge building. In particular, wikis seem to be conducive to authoring and publishing jointly produced information resources. However, tensions emerge when the historically individual and private character of writing is mediated by a technology that has shared ownership and transparency as its main features. Therefore, an emerging research issue in the study of knowledge advancement in institutional learning settings is the critical examination of wiki features that may facilitate transitions from individual to collective epistemology.

The design theme addresses the design of affordances and domain specific features in wiki technology. An emerging research issue related to technologies that develop 'outside institutions' is the characteristics they develop when taken up in learning contexts in institutional settings. Therefore this workshop investigates design principles and affordances that uphold the collaborative, democratic features of wiki architecture when used in the more individual, goal-directed efforts in school and work settings. The design theme thus specifically addresses how prompts, categories and meta-level features may be inscribed in the wiki learning environments to scaffold collaborative learning activities.

The contribution of the workshop is to make apparent the link between the potential of wiki technology and CSCL perspectives on 'how to' design for collaborative practices of knowledge advancement. The use of wiki-based approach in this context as a starting point for exploring how the wiki notions of shared construction of knowledge can be applied and extended to scaffold complex collaborations in institutional and educational settings, and in mixed virtual and physical world contexts.

The strong link between knowledge advancement and design research within CSCL is at the core of this workshop that investigates the social and educational use of wikis. These issues are explored 'hands-on' in advance, during, and after the workshop. The organizers have established a wiki environment at www.intermedia.uio.no/wikiresearch/ that will be sustained in order to pursue research issues before but also after the conference, as an outcome of the workshop. Themes and topics that have emerged from the pre-conference research wiki will be used during the workshop as points of departure for a user story design method where participants are assigned 'situations'. Participants develop a user story related to a specific problem in which wikis can be used. These will be presented, discussed, and summarized in order to further develop wiki research.

The workshop will be held all day on Tuesday July 17. The organizers come from different research fields such as informatics, design and the learning sciences but all with substantial experience with wikis.

Introduction to Computer Supported Collaborative Learning

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Overview of the tutorial

CSCL (Computer Supported Collaborative Learning) is an emerging field of research and practice on learning, aiming at both enhancing quality of learning and promoting its scientific understandings. To introduce the depth and breadth of the theories and practices of CSCL in more details in the limited time allocated to this tutorial, I focus on some theoretical perspectives on collaboration as the basic form of high quality learning, with research evidence. To do this I would encourage the participants to engage in collaborative, constructive interaction among themselves on the following topics focusing on theoretical backgrounds of collaboration, to secure the cognitive bases to understand, design and engage in CSCL research and practice.

COLLABORATIVE LEARNING: HOW IT WORKS
Socio-cultural studies on collaborative learning
Collaborative enhancement of motivation for comprehension
Collaboration for constructive comprehensive interaction

Brief introduction

We are living in a society with changes at the speed no one has ever experienced in history. This situation requires learning of high quality, which no theory of learning in the past appears to be adequate to guide. The goal of such learning is not the learning of facts, but of flexible, generative knowledge not bound with concrete situations where it is learned. To fulfill such a goal, new research on learning takes collaboration as its form seriously, and implements and evaluates technological support to materialize effective learning designs. Research in CSCL allows researchers, practitioners, and other stakeholders design successful practices of fostering the growth of intellectual societies, and build scientific theories of learning, so that the successful practices and robust theory building can feed into each other.

Computers play indispensable roles in CSCL because of the following two reasons. One is that the new type of learning research requires recording and analyzing the processes of learning, with greater details for a much longer period than conventional, laboratory based learning studies. The other reason comes from the design requirements for collaborative learning, which call for making thinking visible, sharable, reflect-able, and modify-able by the participating learners. Currently, computers and computer-controlled recording and analyzing tools are most promising to meet these requirements.

In current CSCL research learning is regarded as a social process, where each learner, is responsible for creating one's own knowledge through social interaction with other human beings, by interacting with physical objects, in everyday situations. Each learner works toward achieving "adaptive" or generalize-able expertise (Hatano and Inagaki, 1986). One of the most popular types of implementing this consensus is the collaborative learning. The theoretical foundation of CSCL has to explain why collaborative cognitive processes lead to the acquisition of the generative, adaptable pieces of knowledge. This is the main reason why I would like to aim this tutorial to socially construct our basic understandings on theories of collaboration. It would also be nice if we could conclude this tutorial with some remaining challenges for future studies in CSCL.

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An Interactive Session Using a Tool to Support Distributed Conversations around Digital Video

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Workshop Theme and Objectives

Jordan and Henderson (1995) outline a research methodology they term *interaction analysis*—a powerful method for investigating human activity in which a group of researchers come together in a meeting to offer their insights on some video recorded event. Although the interaction analysis approach proved to be highly influential for ethnographers and other social scientists, it was limited by the technologies available at the time of Jordan and Henderson's writing (VHS tapes, etc.). Reconstructing the contextually grounded insights of researchers can be an onerous task, not to mention the challenge of accommodating the schedules of several busy researchers. Fortunately, the decreasing costs and increased accessibility of digital video technologies has made it possible to support fluid conversations around a video record without the constraints of an in-person meeting. Pea, Lindgren, and Rosen (2006) present a framework for enhancing interaction analysis with internet technologies that they term computer-supported collaborative video analysis (CSCVA). They also describe a software environment designed to facilitate CSCVA in the research community called DIVER (Digital Interactive Video Exploration and Reflection). The purpose of this session will be introduce to participants the theoretical issues around CSCVA and give them practice collaborating on video analysis using the DIVER platform. Session participants will have access to a large video data corpus that we have collected on families discussing the role that mathematics plays in activity at home. The goal of the session is to build fluency among participants with CSCVA tools and to have them recognize the potential for using these types of tools to improve and expand their research practices.

DIVER

DIVER is a web-based application that allows researchers to use their web browser to view digital video clips and add text annotations to specific points in space and time within the video; it is an authoring process that we refer to as making a "dive" (Pea, 2006). By controlling a viewing rectangle that is overlaid on the video, a researcher can direct the attention of other researchers to the specific points that support the argument they are trying to make about the activity in the video (see Figure 1). The DIVER application includes several additional features that support conversation around video amongst distributed individuals, including the capabilities of: (1) integrating the analyses from multiple video sources into a single dive; (2) "remixing" a dive into a stand-alone presentation of the video analysis; and (3) sharing specific dive segments (e.g., zoomed region of an interaction for a temporal subset of the clip) with annotations through an e-mail webpage link. DIVER is one of the research tools in use by researchers and partners of the NSF funded Science of Learning Center known as LIFE (Learning in Informal and Formal Environments: http://life-slc.org/).

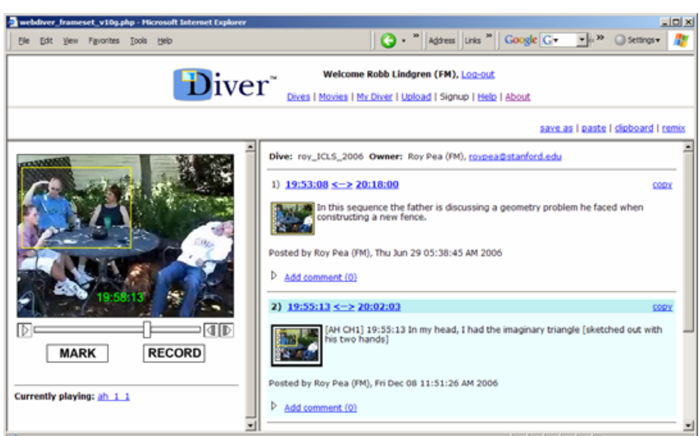

Figure 1. A researcher's dive on a Family Math Project video. The researcher has used the viewing rectangle to the draw attention to the gestures the father uses to describe the geometry problem he was working on.

The Family Math Project Video Data Corpus

The small group video analysis activity in this session will utilize a large set of digital videos recorded by the Family Math Project, another major initiative of the LIFE Center. The goal of the Family Math Project is to identify the cultural contexts that are relevant to mathematics learning and practice, to identify the resources family members use for solving problems together, and to characterize the structure of these activities. The data set includes over 40 hours of videotape from interviews with 20 families where we sought narrative accounts of math in the daily lives of family members.

Session Activities

This event will consist of 3 core activities:

- **A presentation on the theoretical foundations of DIVER and CSCVA.** We will present a brief history of video analysis, challenges for supporting collaborative analysis, and how these challenges have been addressed by software solutions such as DIVER.

- **A DIVER tutorial.** We will show examples and conduct a hands-on tutorial showing the important features and functionality of DIVER.

- **Small group activity working with Family Math Video.** Participants will break into small groups and will conduct their own theoretically-driven analysis of one or more of the available videos. Session organizers will be on-hand to answer both technical and research-orientated questions.

Session Organizers

Roy Pea is a Professor of the Learning Sciences and Director of the Stanford Center for Innovations in Learning, LIFE Center Co-PI, and Co-Lead on the Family Math Project. He has written extensively on distributed cognition, learning and education fostered by advanced technologies including scientific visualization, on-line communities, digital video collaboratories, and wireless handheld computers. His current work involves developing a new paradigm for everyday networked video interactions for learning and communications, and research concerning how informal and formal learning can be better understood and connected.

Shelley Goldman is a Professor of the Learning Sciences and a Co-Lead on the Family Math Project. She is an educational anthropologist working at the intersections of technology, mathematics education, and “best learning practices” who engages video analyses in research.

Robb Lindgren is a doctoral candidate in the Learning Sciences and Technology Design program at Stanford and has been part of the DIVER project team for over 3 years.

Joe Rosen is the senior staff research software engineer at the Stanford Center for Innovations in Learning. He leads the technical programming and maintenance of the DIVER tool-set.

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Chat Analysis in Virtual Math Teams

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Text-based synchronous chat can provide a powerful CSCL medium if properly structured and presented. The Virtual Math Teams (VMT) project at the Math Forum and Drexel University has developed an online environment combining chat and a shared whiteboard for discussion of math, run many trials with students and conducted detailed analysis of numerous interactions that took place. A number of chat analyses from the VMT data will be presented and discussed in this workshop.

Chat analysis as practiced in the VMT project is an ethnomethodologically-informed approach to micro-analysis of brief excerpts of online interaction in small groups. The approach adapts the rigorous methodology of Conversation Analysis to the text-based, distant interaction among math students discussing a topic or problem.

The focus of the workshop will be on the analysis of meaning making, group cognition and collaborative knowledge building in small online groups engaged in math discussion. The goal will be to share, discuss and extend findings and results of analysis of excerpts from the VMT project. This workshop will result in:

- Exposure of the audience to hands-on experience with interaction analysis of chat.
- Deepening of the analysis of data that is presented.
- Development of theoretical and methodological understanding of chat analysis.

There will be several presentations during the day. The presentations will each take one of the following formats:

- A data session in which the presenter leads the audience in analysis of a chat excerpt.
- A theoretical paper and/or discussion related to the nature of meaning making, group cognition or collaborative knowledge building in chat interaction.
- A methodological paper and/or discussion of techniques for the analysis of intersubjective meaning, shared understanding or social practices in small online groups.

Each presentation will include a presenter or facilitator, a commentator or critic and audience participation.

The presentations will be selected from among recent analysis efforts associated with the VMT project in Spring 2007. They will be selected on the basis of their suitability for a balanced workshop program, including early looks at new data, more established analyses, theoretical concerns and methodological proposals.

The workshop will be held all day on the Monday preceding the CSCL 2007 conference. It is open to researchers interested in chat analysis on a first-come basis.

Gerry Stahl, the Director and PI of the Virtual Math Teams project at the Math Forum and Drexel University will organize the workshop. Colleagues from the VMT project will assist in organizing and conducting the workshop. Stahl teaches, publishes and conducts research in human-computer interaction (HCI) and computer-supported collaborative learning (CSCL). His new book, *Group Cognition: Computer Support for Building Collaborative Knowledge* is published by MIT Press. He is founding Executive Editor of the *International Journal of Computer-Supported Collaborative Learning* (ijCSCL). He served as the Program Chair for the CSCL '02 conference, and a Workshops Chair for CSCL '03, CSCL '05, ICCE '06 and CSCL'07. He ran a similar workshop on chat analysis at ICLS 2006 in Bloomington—the workshop was very successful and attracted a full audience, however, there was too little time to go into depth with the analyses; that is why this workshop will focus on data from one project.

Towards the Convergence of CSCL and Inquiry Learning: Scripting Collaborative Inquiry Learning

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> The use of the collaboration technology must be highly structured, with a systematic didactic approach, continuing teacher involvement and periodic face-to-face meetings to troubleshoot problems and reflect on the learning process. These suggestions [...] should only surprise people – if there still are any – who think that putting a computer box in a classroom will promote learning by itself.
>
> (Gerry Stahl, 2006, p. 221)

Inquiry Learning is regarded as a prominent approach to facilitate the construction of knowledge in science education. Educational psychology has devoted strong efforts to the development of web-based collaborative inquiry learning environments in recent years. Learners can explore scientific phenomena in these environments, they can gather and present data or set up hypotheses for example (see Schwartz, Lin, Brophy, & Bransford, 1999). According to Quintana and colleagues (2004), main processes of inquiry are posing questions and try to answer these questions with empirical data. Thereby, learners either conduct experiments their self or compare outcomes of already existing datasets. There are a number of examples for web-based collaborative inquiry learning environments: WISE (Slotta, 2004), CoLAB (van Joolingen et al., 2005), or BGuILE (Reiser et al., 2001), to name a few. Various scaffolds are implemented in these environments with the aim to stimulate substantial elaboration of the subject matter. Therefore, the attention of the learners has to be to channeled and focussed on relevant concepts and the mechanisms of the problem at hand (Pea, 2004). Current approaches try combine this approach with ideas stemming from research in computer-supported collaborative learning (see Kollar, Fischer, & Slotta, 2005). Parts of the inquiry cycle, e.g. the evaluation of empirical data, can be executed collaboratively. While the inquiry cycle is often scaffolded in order to facilitate essential inquiry processes, support of the collaborative activities is often lacking or even missing. Learners might get asked to discuss two conflicting hypotheses for example, but subsequently won't get supported to construct complete arguments and well-formed argumentation sequences. Computer-supported collaboration scripts based on the scripted cooperation approach (O'Donnell, 1999) can help facilitating collaborative processes like argumentation. An interface integrated in a computer-supported learning environment may suggest the construction of specific arguments by providing prompts that learners should use or respond to respectively (e.g., Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2002).

Furthermore, interfaces may be designed to specify, sequence and eventually allocate different learning activities to different learners. Empirical research suggests that computer-supported collaboration scripts can support specific processes and outcomes of argumentative knowledge construction, but they might have "side effects" on others (see Dillenbourg, 2002; Weinberger et al., in press). Kollar and his colleagues (2005) investigated computer-supported collaboration scripts that provided text spaces for claims and evidence learners had to fill in, as well as a specific sequence of arguments, counterarguments and integrations. Learners acquired domain-specific knowledge independently of the script support in this study. However, the computer-supported collaboration scripts facilitated the acquisition of knowledge on argumentation as an outcome of argumentative knowledge construction. These first results indicate the strong potential for a merger of research on collaboration scripts and inquiry learning.

This full-day workshop aims at working out the synergies of computer-supported collaborative learning and Computer-Supported Inquiry Learning in an attempt to define a possible research agenda for Computer-Supported Collaborative Inquiry Learning and to identify demands on the future development of software tools supporting this joint approach. Hence, the workshop will address issues interesting for Computer Scientists, Educational Scientists, as well as Educational Psychologists. The workshop will be divided into three phases: The first phase consists of input talks from the fields of research, namely Computer-Supported Collaborative Learning and Computer-Supported Inquiry Learning, as well as the current state of the art of software development in these approaches. During the second phase, research will be presented that examines overlapping learning scenarios, e.g. scripted collaborative inquiry learning. Within the third phase, participants will work in small groups on the theoretical implications for a joint approach of "computer-supported collaborative inquiry learning", the demands on scripts resulting from this joint approach, and the demands for further software development for collaborative inquiry learning. There will be a special track for PhD students during this last phase. Senior researchers will discuss with the PhD-students their studies against the background of how to implement Computer-Supported Collaborative Inquiry Learning.

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Acknowledgments

The organization of this workshop is partly funded by the European Network of Excellence Kaleidoscope (http://www.noe-kaleidoscope.org).

Languages and platforms for CSCL Scripts

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Abstract: Learners in unstructured CSCL scenarios often have difficulties to engage in specific collaborative learning activities, such as question asking, elaboration, or constructing sound arguments. An increasing amount of CSCL research therefore deals with the question how scripts can help learners to fully benefit from CSCL environments. The objective of the workshop is to study the questions related to the implementation of CSCL scripts, from their modeling to their effective deployment on a given platform.

Implementing Scripts in CSCL Platforms

Scripts are sequences of roles and activities provided to learners to facilitate specific learning processes. There is empirical evidence that scripts can foster CSCL beyond individual computer-supported learning and that – depending on their design and goals – scripts can facilitate specific activities and outcomes of collaborative learning. CSCL scripts are implemented in and typically hard-wired to specific platforms. Different actors (students, teachers) loosely follow script guidelines to achieve their tasks, such as implementing collaborative phases into classroom education (teacher) or solving a complex learning task (students).

Transferring Scripts between Platforms

Hard-wired scripts are difficult to transfer to different contexts and platforms. One approach to make scripts transferable between different platforms is formalization, i.e. describing scripts in a machine-readable language. Thus, scripts can be run in general-purpose platforms, such as LMS, providing generic communication tools or data exchange facilities. In such a case, script and platform are connected only via a standard interface (i.e. the script definition language, which must be interpreted by the platform).

The objective of the workshop is to question the interest and explore the means for interconnecting the script and the platform, i.e., presenting students and teachers with platforms that are tailored according to (based on, customized for) the script structure. The objective of the workshop is to study the questions related to the implementation of CSCL scripts, from their modeling to their effective deployment on a given platform:

- How does tailoring the platform according to a script influence processes and outcomes of CSCL (guiding the learner; proposing integrated tools; adapting to the actual performance; etc.)?
- How does tailoring the platform according to a script support teachers in realizing CSCL (perceiving or supervising the setting; adapting the setting; etc.)?
- How can scripts' flexibility issues be handled in run-time?

Workshop Organization

The workshop features contributions that focus on the theoretical background and empirical findings on CSCL scripts to first set the stage for participants of different backgrounds (educational practitioners and researchers of educational science, educational psychology or computer science). Second, analyses of given languages or platforms for CSCL scripts will be discussed. Third, participants will create scripts that they will be able to use in their own settings with different types of languages and platforms.

Intended audience

The workshop is intended for educational practitioners of all domains and researchers of educational science, educational psychology and computer science interested in modelling languages and operationalization platforms that create and implement CSCL scripts. There is opportunity for participants who have developed modeling languages and/or operationalization platforms to present their approach and make their tools available for hands-on activities during the workshop.

Organizers' names and backgrounds

Dr. Armin Weinberger: Research fellow and lecturer at the Chair of Education and Educational Psychology, Department of Psychology, University of Munich, and Leader of the EU-funded European Research Team CoSSICLE (Computer-Supported Scripting of Interaction in Collaborative Learning Environments).

Prof. Miky Ronen: Head of the Instructional Systems Technologies Department at the Holon Institute of Technology and a fellow at the Technologies in Education graduate program at the Haifa University. Leading an R&D group on CSCL.

Prof. Pierre Tchounikine: Head of the computer science laboratory of the Le Mans University (France), involved in the CSCL activities of the European Kaleidoscope network of excellence, advisor of different PhDs related to CSCL.

Dr. Andreas Harrer: Scientific assistant and lecturer at the Collide research group, Department of Computer Science and Applied Cognitive Science, University of Duisburg-Essen, steering group member of the European Research Team CoSSICLE, working there on computational formalization of CSCL scripts with the perspective on executing the scripts automatically.

Prof. Pierre Dillenbourg at the Swiss Federal Institute of Technology in Lausanne, Switzerland has conducted research on CSCL scripts for several years. He is the editor of the Springer CSCL Book Series.

Prof. Jörg Haake: Chair for Cooperative Systems at the Department of Mathematics and Computer Science of the FernUniversitaet in Hagen, Germany, is leading the continued development of FernUni's open source collaborative learning platform CURE. His current research is on design, implementation and use of CSCL scripts in distance teaching situations.

Dr. Yael Kali: Senior Lecturer at the Technion, specializing in educational technology and design principles for web-based learning. As a co-PI at the NSF-funded TELS (Technology Enhanced Learning in Science), Kali and her group at the Technion developed the Design Principles Database (http://design-principles.org) to coalesce design knowledge from leading educational technology research groups.

Prof. Frank Fischer of Education and Educational Psychology at the University of Munich, Germany was formerly professor of Research on Learning and Instruction at the University of Tübingen and head of the research unit "Collaboration Knowledge Construction" at the Knowledge Media Research Center in Tübingen.

Dan Kohen-Vacs: Lecturer and staff member of the Instructional System Technologies department at the Holon Institute of Technology and a Ph.D. student at the Technion. The Development manager of the the CeLS project.

Mice, Minds, and Society

Doctoral Consortia

Computational Metaphor Extraction to Encourage Critical Reflection and Support Epistemological Pluralism

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Abstract: Critical reflection can be an important component of metacognition in learning, but teaching the techniques of critical reflection is a difficult challenge. This proposal describes how computational metaphor extraction could be used to encourage critical reflection in learners. Metaphorical relationships between different concepts may be one way of describing the epistemological approach, "mode of thinking," or framing adopted by a learner. Furthermore, asking students to explain these relationships may present a novel method for fostering critical reflection in learners. This proposal outlines the project's theoretical and pedagogical underpinnings, describes the implementation of a computational method of extracting metaphorical relationships from textual corpora, lays out a plan for deployment in a variety of educational settings, and presents methods for evaluating the project's efficacy in fostering critical reflection.

Introduction

A considerable amount of educational research has already been done on teaching adults critical reflection (Mezirow, 1990; van Aswegen *et al.*, 2000). However, relatively little research has focused on fostering critical reflection in adolescents and young adults. Some have argued that the capacity for critical reflection is specific to adult learners (Mezirow, 1990), but little empirical research has demonstrated that younger individuals lack this capacity. This thesis proposes exploring the possibility of teaching critical reflection to learners ranging from school-age children to university students. Critical thinking and critical reflection are not often explicitly encouraged or rewarded by current educational trends, such as those embodied by the No Child Left Behind act (2002), or long-standing educational traditions, such as standardized testing. The project described here seeks to foster the capacity for critical reflection through a novel technological system. In particular, it focuses on metacognition, that is, the learner examining his or her own ways of thinking and learning. Turkle and Papert (1991) describe the concept of epistemological pluralism, wherein different conceptual approaches are taken by students learning to program computers. Turkle and Papert characterize students as taking either the "hard" approach, which emphasizes on abstractionism and black-boxed program components, or the "soft" approach, which closer resembles bricolage and connects together many smaller pieces. The position taken in this paper is that epistemological approaches can be much more diverse than only "hard" or "soft," and one way of describing a learner's epistemological approach is by determining the metaphors that they use to understand the material presented to them.

Lakoff and Johnson (1980/2003) describe how metaphor is not merely a poetic or linguistic device, but is fundamental to our daily lived experience. Furthermore, these metaphors are evident in our everyday language. For example, the phrases "your claims are indefensible," "her critique was right on target," "I demolished his argument," and "I've never won an argument with him" all evince images of physical combat and demonstrate the metaphor ARGUMENT is WAR. However, this is not the only possible metaphor for argument. In other cultures, the language used to describe an argument is more akin to a dance, in which two performers verbally maneuver around one another in order to collaboratively create an aesthetically pleasing experience for themselves and for others. Neither metaphor is right or wrong; rather, each highlights or downplays different aspects of the same situation. Lakoff and Johnson argue that "successful functioning in our daily lives seems to require a constant shifting of metaphors" (1980/2003). This proposal argues that becoming more aware of the metaphors one uses in his or her writing can facilitate the ability to consider alternate, metaphorical framings of a given situation. While incorporating such close examinations of students' writing in common curricula would be one way of improving awareness of metaphor and fostering critical reflection, the methods involved are time and labor intensive, and the most recently published statistics place average student-to-teacher ratios for the US at approximately 16:1 (2005), thus limiting the amount of personalized attention a teacher can give each student. This proposal explores a technology-based approach that may make tractable the encouragement of critical reflection given the current situation.

The approach proposed here uses computational linguistic methods to extract metaphorical relationships in textual corpora. Computational techniques can be particularly illuminating, for example, in showing trends of interest and changes of rhetoric in the US congress (Quinn *et al.*, 2006). There has also been research into automatic evaluation of students' writing, e.g. (Warschauer & Ware, 2006). Since such results can be quite informative to researchers studying textual corpora or teaching trying to grade student papers, perhaps it would also be beneficial to provide some of that analysis as feedback to the individuals who produced the texts. The specific project proposed here is based on a computational method of extracting metaphorical relationships in textual corpora (Mason, 2004). This thesis proposes to apply computational methods of metaphor extraction to students' writing about the material they learn in their classes, arguing that the extracted metaphors may be one way of exposing the epistemological approach or approaches being used by students to learn the material. Presenting students with these metaphors has at least three possible benefits. First, increasing awareness of a student's own learning and thought styles may improve his or her learning. Second, awareness on one's thought style can lead to critical reflection and openness toward alternate thought styles. Third, building an understanding of, and appreciation for, different thinking and learning styles may facilitate communication between learners.

Implementation

The implementation proposed here draws largely from CorMet (Mason, 2004), a computational method of extracting metaphorical relationships between textual corpora from different subject domains. To do this, CorMet first parses each document and compiles a list of verbs that have a high frequency of occurrence in each domain relative to their frequency in general English. For each of these characteristic verbs in a domain, the algorithm performs selectional preference learning to determine the type of words for which each verb's case slots tend to select. For example, in the LAB domain, which refers to a chemistry or biology laboratory, the verb "pour" has a selectional preference for liquids as its direct object. To detect metaphorical mappings between two domains, the verbs with the strongest selection preferences for one domain are examined in another domain to determine if those same verbs have a strong but different selectional preference in the second domain, but not vice versa. For example, "pour" in the LAB domain tends to select for liquids, whereas "pour" in the FINANCE domain tends to select for money. However, other verbs in the finance domain that select for money, such as "spend," "invest," or "deposit," do not select strongly for liquid in the LAB domain. Thus, we can see that there is a metaphorical mapping from liquid to money. For more details, see (Mason, 2004). It is likely that, during the process of this implementation, certain aspects of the original CorMet techniques will need to be modified or improved. For example, CorMet uses predominantly frequentist probabilistic learning methods, which rely heavily on having very large corpora. It may be more effective instead to use Bayesian learning methods that use prior assumptions to reduce the number of observations required, or to train the algorithm on established corpora and then use the results of this training to detect metaphorical relationships in other documents.

Furthermore, it may be beneficial to be able to detect in a single document or small corpus instantiations of common, well-established metaphors. In order to accomplish this, we plan to use an algorithm like CorMet to build a database of common metaphors, such as that between liquids and funds described above. Such a database would represent metaphors as pairs of selectional preferences, including the verbs involved, the clusters of words to which each of those verbs maps, and the direction and strength of the mapping. In order to locate metaphors in a novel document or corpus, the system finds the selectional preferences for the verbs in that document or corpus. These selectional preferences are compared to those in the established database. If the selectional preferences encountered in the novel document or corpus correspond to any in the database that are the target of a metaphorical mapping, then that metaphor is presented as a possibility that may be occurring in that document. For example, if a novel document contains verbs like "pour," "flow," or "freeze" that exhibit a strong selectional preference for words like "assets," "funds," or "money" in one of their case slots, them the metaphor of MONEY is a LIQUID will be presented as possibly occurring in this document or corpus. An important point to consider is that the novel document or corpus may or may not contain the metaphor described. Furthermore, there may be many metaphors that the system does not automatically recognize. The goal of the system, though, is not to accurately discover every single metaphor in a document or corpus, but rather to present some possible suggestions of metaphors that may be present as a means of encouraging critical reflection.

Evaluation

At the time of submission, a pilot study is planned to determine the most effective results of the computational analysis described above at engendering critical reflection in students. The pilot study will use data from an undergraduate writing course on the social analysis of computing. The written materials produced for the class include a number of weekly summaries for assigned readings, which are largely academic publications about social aspects of computing and computational technologies, as well as two longer papers. Copies of the assignments will be collected and analyzed using the methods described above to try and find metaphorical relationships in students' writing. The results of this analysis will be presented to students, who will then be asked how they see the resulting metaphors as relating to their work. Questions such as the following will be asked. Which metaphors make the most sense? Are there specific examples in your writing where you see this metaphor occurring? What aspects of the situation does this metaphor emphasize? What aspects does it hide or downplay? Are there any metaphors that do not make sense?

This proposal also includes plans for a longer, more in-depth study of regular use of this system by a variety of learners. Students will be asked to make an entry in an electronic journal describing what they learned that day about a specific subject or in a specific class, such as mathematics, language arts, science, social studies, art, physical education, or friends and family. Using the method described above, metaphorical relationships that occur in the students' writing will be computationally extracted and presented to the students. For example, the above mapping between liquids and money would be presented as "money is like a liquid." The exact presentation of these metaphors and questions about them will be guided by the pilot study described above. Those aspects of the metaphors that prove most useful to students in the pilot study will be emphasized, and accompanying questions will focus on these aspects. The success of the project will be determined by the degree of critical reflection that occurs in the students' responses to these questions. The goal of this work is that, by making them more aware of different possible approaches to a situation or problem, students will develop greater cognitive flexibility and diversity, improving their problem solving skills with the ability to reframe and rethink the problem, and ultimately encouraging them to engage in critical thinking about their own and others' epistemological approaches.

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Acknowledgments

The author thanks his advisor, Professor Bill Tomlinson, and acknowledges the support of the Donald Bren School of Information and Computer Sciences, the California Institute for Telecommunications and Information Technology, the Emulex Corporation, and the Social Code Group at UCI for their support.

How Online Small Groups Create and Use Mathematical Objects to do Collaborative Problem Solving

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Understanding how students learn mathematical concepts and developing pedagogies to scaffold mathematical sense making are central issues in the field of math education. Mathematical work is often characterized as developing organizational practices over a peculiar set of entities referred to as *mathematical objects* (Livingston, 1987; Dorfler, 2002). Existing theories of mathematical concept formation put special emphasis on the process of *reification* (Sfard & Linchevski, 1994; Dubinsky, 1991; Gray & Tall, 1994), which involves the transformation of activities performed in specific problem-solving situations (e.g. the process of addition) into mathematical objects (e.g. the concept of sum) that have a structure in their own right at a more abstract level. In other words, a process is said to be reified into an object when "…the individual becomes aware of the totality of the process, realizes that transformations can act on it, and is able to construct such transformations." (Cottrill et al., 1997, pp.). Recent contributions to this theoretical discussion highlight the communicative role of math objects, and situate them in *mathematical discourse,* which is claimed to lend these objects their meaning and existence (Sfard, 2000; Sfard, 2002; Dorfler, 2002; Cobb et al, 1997). The characterization of math objects in this way attributes an *interactional* status to the reification process through which learners co-construct and make sense of such objects as local achievements of their interactions with their teachers/peers through the mediation of various linguistic/symbolic/representational artifacts. This emergent and situated nature of math objects suggests that an understanding of their use requires a close, moment-by-moment analysis of the mathematical activities that produce them.

Computer-Supported Collaborative Learning (CSCL) is a recently emerging paradigm in the field of educational technology which is "…centrally concerned with meaning and practices of meaning making in the context of joint activity and the ways in which these practices are mediated through designed artifacts" (Koschmann, 2002). In the field of CSCL, providing a context for joint activity supported by computing technology is considered to foster learning through an interactive process where participants naturally articulate, make sense of and build upon each other's perspectives (Stahl, 2006). Consequently, a CSCL environment potentially offers a perspicuous setting for studying the organization of activities that produces math objects from an interactional perspective. Especially a collaborative setting where the communication is mediated by computers opens the possibility for capturing the sequence of actions in which math objects are co-constructed in the context of joint activity. Moreover, the possibility of making persistent records of interactions available to participants potentially allows them to inspect their ongoing activity, explore alternative organizations of their shared content, and build new mathematical constructions on top of what they have been working on as a group. This dissertation will explore these possibilities by investigating how groups of students enact the affordances of a particular CSCL environment called Virtual Math Teams to create and use mathematical objects to do collaborative problem solving.

Research Context

This dissertation work is being conducted within the context of the Virtual Math Teams (VMT) Project at Drexel University. The VMT project is an NSF-funded research program through which an interdisciplinary group of researchers investigates innovative uses of online collaborative environments to support effective K-12 mathematics learning. The project aims to extend the existing services of the Math Forum to solicit active participation of students to discuss math problems together and to share their findings/experiences with other members of the Math Forum online community. In particular, the project is developing a service that includes a chat-based communication tool called VMT Chat and an integrated wiki component to support collaborative knowledge building activities online. The chat tool provides two main interactive components, namely a text-based chat and a shared whiteboard. One of the unique features of this chat system is the referencing support mechanism that allows users to visually connect their chat postings to previous postings or to graphics on the board (Mühlpfordt & Wessner, 2005).

Research Questions

This dissertation work will investigate how small groups of students co-construct mathematical objects, make sense of them jointly, and incorporate them into solution accounts through online communication tools offered by the Virtual Math Teams service. The analysis will primarily address the following research questions:

1. How are representations co-constructed and reified as socially meaningful *math objects* through their use in the problem solving context?
2. How do sketches and text-boxes on the whiteboard as well as chat postings serve as *referential resources* for problem solving, and how does their availability set the context for subsequent interactions within the environment defined by these media?
3. How is mutual intelligibility achieved through the organization of math objects within the shared space and how does this organization help to produce shared *solution accounts*?

The specifics of the software environment strongly influence the interaction methods used by the student participants. In particular, the fact that VMT offers a multimodal communication platform requires participants to organize their actions across different spaces in intelligible ways. (Stahl et al., 2006; Mühlpfordt, 2006; Dillenbourg & Traum, 2006). Hence, the role of the affordances of the environment will be studied with the following questions involving the co-constructed math objects:

4. What are the similarities and differences between construction, reification, and use of math objects in the different *interaction spaces* (i.e. in the chat, in the white-board and in the wiki)?
5. How do participants *enact the affordances* of multiple interaction spaces to manage and organize a shared space of math objects?
6. How do members *coordinate their activities* with math objects across the interaction spaces in order to accomplish their group problem solving tasks?

Research Approach

A Design-Based Research (DBR) approach will be employed to investigate the research questions listed above. As Barab stated "…the main goal of DBR is to use the *close study* of a single learning environment as it passes through *multiple iterations* and as it occurs in *naturalistic contexts*, to develop new *theories*, *artifacts*, and *practices* that can be generalized to other schools and classrooms." (2006, p153). In particular, this dissertation will contain three studies, where each study will include 4 to 5 groups each having 2 to 4 middle school students who will collaboratively work on an open-ended math problem in the VMT environment. After each study a close analysis of the collected data will be performed to investigate how groups organize their collaborative problem solving work with the available features. The analysis will be based on the adaptation of Conversation Analysis (CA) techniques to online chat (Garcia & Jacobs, 1998; O'Neil & Martin, 2003), and will be informed by the ethnomethodological investigation of mathematicians' work (Livingston, 1987) and the studies of scientists' representational practices in the context of Sociology of Scientific Knowledge (Lynch & Woolgar, 1990). By considering the group as the unit of interest (Stahl, 2006) the analysis will be geared towards documenting the methods that participants demonstrated as they co-construct math objects and engage in math discourse to produce a shared solution account.

The findings of the analytical work will then be incorporated into design decisions to improve the VMT service. For instance, our preliminary findings from studies conducted in April 2005 and April 2006 indicate that the whiteboard space offers a more flexible area to manage group contributions due to its more persistent nature and better content management capabilities. Moreover, the possibility of re-organizing and annotating the whiteboard content potentially reveals how individual contributions are related to each other and hence possibly make the collective reasoning process underlying that organization more transparent to the members of the group. Most importantly, the availability of an evolving sequence of problem-solving steps on the more persistent space may render the reasoning behind that organization a relevant matter for the group to talk about in chat, and hence potentially facilitate the reification of that ongoing process into a larger mathematical object. The scenarios based on the use of multiple media and functionality to support the reification process in this manner will be investigated further in our upcoming case study in April 2007. Segments from the three studies that are relevant to the research questions will be analyzed in detail in order to provide grounded answers to the proposed questions.

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Knowledge Mirroring: Fostering Computer-Mediated Collaboration and Learning

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Abstract. For collaborative learning to be effective learners need to construct adequate models of their partner. Partner modeling is often not accurate and is particularly impaired in computer-mediated scenarios. In this paper Knowledge Mirroring is discussed as a means of supporting collaboration by providing learners with information about their partner's knowledge. The effect of Knowledge Mirroring on the producer side of knowledge communication was studied in a first experiment. Contributions to computer-mediated knowledge communication were found to be adapted according to the information about the partner's knowledge. Subjects provided with Knowledge Mirroring performed better than participants of a control group in an inferential knowledge test. The conceptualization for a second experiment is presented that will study effects of Knowledge Mirroring on both producer and recipient side of knowledge communication.

Problem Statement

The notion of "shared understanding" lies at the very heart of CSCL (Roschelle & Teasley, 1995). In order for collaborators to be able to negotiate, construct and maintain a shared understanding, they need a representation about their partner's understanding and knowledge. Whereas in face-to-face (ftf) collaboration these resources are more easily accessible, computer-mediated scenarios pose difficulties on the process of partner modelling. More specifically regarding the models of a partner's knowledge, initial models are biased towards the model of one's own knowledge (Nickerson, 1999). Even worse, common strategies of verifying partner models are frequently ineffective (Chi, Siler & Jeong, 2004). To compensate for this problem technological support is developed that provides collaborators with information about their partner's knowledge.

Knowledge Mirroring

Research in the field of CSCW has used *awareness tools* for some time. Awareness tools typically inform group members about the presence of other group members, their activities and tasks. The main focus of these tools in CSCW is on compensating for the lack of backchannel feedback and non-verbal cues compared to ftf scenarios e.g. with video-conferencing systems (Gutwin, Greenberg & Roseman, 1996). In this paper a project is presented that follows a different rationale of computer-support by providing information about latent variables (e.g. affective, cognitive or motivational states) that are not accessible in ftf situations (Buder & Bodemer, 2007). Computers facilitate the registration, transformation and representation of these new information resources. *Knowledge Mirroring* (KM) is implemented in computer-mediated knowledge communication among peers (see Figure 1). It provides collaborators with a graphical representation about their partner's knowledge. As knowledge is presented just as it was determined, i.e. without further calculation, the method is classified as *mirroring tool* (Soller, Martinez, Jermann, & Muehlenbrock, 2005). Persons´ own knowledge is also presented in the KM-Tool, thereby allowing for comparison of own and partner knowledge. Relating to single knowledge units, three possible distributions can emerge as indicated by Figure 1: shared knowledge, shared deficit, and complementary knowledge.

Impact on Collaboration

The project aims at investigating the impact of KM on the process and outcome of collaborative learning. A computer-mediated peer-tutoring scenario with question-asking and explanation-giving as basic activities is introduced. Four aspects will be of special interest in the experimental studies, i.e. coordination, communication, participation and learning (see general hypotheses in Table 1). *Coordination* is necessary when dependencies between activities of partners have to be managed (Malone & Crowstone, 1991). KM shows individuals which parts of their knowledge are exclusive. Thus, responsibility for knowledge and activities associated to it is taken more easily. This is suggested to reduce coordination losses of collaboration. *Communication* partners engage in grounding processes (Clark & Brennan, 1991). KM allows establishing common ground with less grounding effort. Communication partners are thus enabled to adapt their contributions to the communicational needs of their partner (i.e. audience design) which can be inferred from the KM-information (Clark & Murphy, 1982). It was shown that the degree of perceived usefulness of one's activities to others has proven to be a predictor of *participation* (Cress &

Hesse, 2004). KM-information can be utilized to estimate the usefulness of one's own contributions for the specific recipient and therefore should increase participation. In order to derive hypotheses regarding the *learning outcomes*, learning of producers and recipients within knowledge communication is differentiated. For the producers, both interpretation of KM-information and audience design elicit activities beneficial for learning. With KM less re-telling but rather elaboration, cognitive re-structuring, and knowledge transforming are expected (Webb & Palincsar, 1996). Recent research on online expert-layperson-communication has shown that awareness of the recipient's knowledge supports experts in providing information effectively with regard to the laypersons knowledge acquisition and understanding (Nückles, Wittwer & Renkl, 2005). It is hypothesized that recipients benefit from KM because it increases relevance, comprehensibility, and elaboration of knowledge communication due to adaptations to the specific recipient (Webb, 1989).

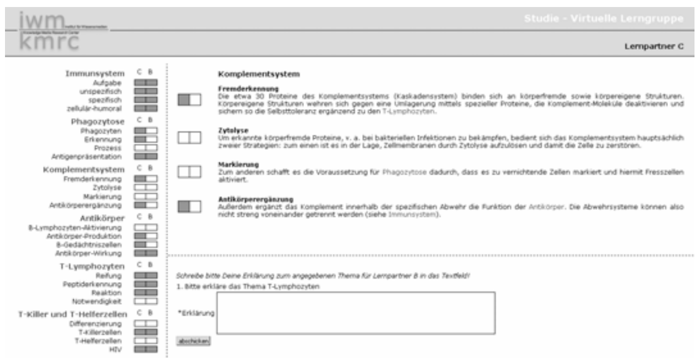

Figure 1. Knowledge Mirroring Tool providing collaborators with their own (left column "C") and their partner's knowledge (right column "B"); green tags indicate knowledge; white tags indicate deficits.

Study 1

A first study was conducted in order to prove the positive impact of KM on the producer of computer-mediated knowledge communication. Hence, a simulated partner was used, i.e. subjects were asked to formulate explanations to a supposed partner. Prior to the simulated collaboration, subjects learned individually with a 6-page hypertext on the immune system. Each page was divided into sections (see Figure 1) which had to be subjectively assessed for understanding. The availability of KM, i.e. these subjective assessments of understanding, was varied as a between-subjects factor. In the control condition only subjects´ own assessments were presented whereas in the experimental condition the assessments of a simulated partner were added. The simulated partners' knowledge was calculated relative to each participant's knowledge with a fixed number of less known sections. Communication and learning of the producer were the main dependent variables. Results indicate that participants in the KM-condition adapted their explanations to the KM-information about their recipient, e.g. with respect to references to text sections and length of explanations. Experimental conditions differed significantly regarding one of the multiple-choice learning outcome subtests measuring inferential knowledge but not in the subtest measuring factual knowledge. Thus, study 1 suggests that the investigation of KM in a real interaction scenario is promising.

Study 2

Design/Method. The availability of KM will be introduced as independent variable again but within knowledge-communication with a real partner. Knowledge to be mirrored is determined by subjective assessments as before. Subjects in the experimental condition will be provided with their partner's subjective estimations. Currently, it is discussed within the project whether and according to which criteria dyads should be matched systematically. The procedure will further differ from study 1 regarding the communication phase. Here, subjects will engage in two basic communicative activities, question-asking and explanation-giving, to discuss their understanding of the complex material. Characteristics of asynchronous communication will be implemented, e.g. by updating procedures (Suthers, Vatrapu, Medina & Dwyer, in press).

Analysis. The main interest is directed towards process variables. Interaction data will be analysed regarding coordination, communication, and participation. Table 1 demonstrates preliminary plans for respective indicators which will be further developed. Learning will be measured with the test of factual and inferential knowledge also used in study 1. In order to not only assess the amount but also the structure of knowledge, subjects will build concept-maps that will be analysed for complexity and interconnection. Another focus of analysis is to determine if the impact of KM on the collaboration process and learning outcome varies depending on specific types of knowledge distribution in the dyads. Thus, the difference of absolute number of self-assessed knowledge (knowledge divergence) and the amount of complementary knowledge units (knowledge complementarity) will be considered as potential moderator variables.

Table 1. Dependent variables and preliminary indicators for study 2.

	General hypotheses	Operationalized hypotheses
Coordination	- Easier distribution of responsibility with KM - Less coordination effort with KM - More role taking with KM	- More simultaneity of contributions with KM - Higher asymmetry of activities (questions versus explanations) in KM dyads
Communication	- Less grounding effort with KM - More audience design with KM	- Less clarification questions with KM - Adaptations of length, references, and elaborations with KM
Participation	- Higher perceived usefulness with KM - Higher participation with KM	- More contributions (questions and explanations) to collaboration with KM
Learning outcome	- More knowledge transforming for producers with KM - Better comprehension of recipients with KM	- Higher amounts of knowledge (multiple choice test) with KM - Higher complexity of knowledge structure (concept-map) with KM

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The Impact of Collaboration on Procedural and Conceptual Knowledge Acquisition in Algebra Learning

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Abstract: Two types of knowledge have to be acquired when learning mathematics: procedural and conceptual knowledge. To some extent, their acquisition is interwoven; nevertheless, students can often correctly solve a problem, but lack a deep understanding of the underlying mathematical concepts. Along these lines, the Cognitive Tutor Algebra, an intelligent tutoring system for high school math education, has proven effective in promoting the acquisition of procedural skills, but has been criticized for not supporting conceptual understanding. My dissertation project proposes to integrate collaboration and more direct conceptual instruction in the Tutor environment to promote the acquisition of both knowledge types.

Knowledge Acquisition in Mathematics: Ways to Support it

When learning mathematics, students have to acquire two types of knowledge: procedural knowledge, which means knowing how to solve problems, and conceptual knowledge, which means knowing the mathematical principles underlying the problems. These knowledge types influence each other: gaining conceptual knowledge usually improves students' procedural skills; however, the impact of procedural knowledge on conceptual knowledge is smaller and less clear, i.e. students that use correct procedures do not necessarily fully understand the domain principles underlying the tasks and have difficulties to transfer the specific procedural skills to new problem types (Rittle-Johnson & Alibali, 1999). How do students acquire procedural and conceptual knowledge? Students can gain procedural knowledge through direct instruction, i.e. by being told how to solve problems (Rittle-Johnson & Alibali, 1999), or through problem-solving practice, i.e. learning by doing (e.g. Anderson, Corbett, Koedinger, & Pelletier, 1995). Conceptual knowledge may also be learned through direct instruction; however, merely solving problems does not necessarily produce an understanding of the underlying concepts. Rather, students have to actively engage in learning to understand the domain principles (e.g. Chi 1996).

One method that has been shown to be effective for promoting procedural learning is problem-solving with intelligent tutoring systems. For instance, the Cognitive Tutor Algebra yields learning gains that are one standard deviation higher than those of traditional classroom instruction (Koedinger, Corbett, Ritter, & Shapiro, 2000). This computer-supported learning environment is widely used in regular classrooms across the U.S. In each curriculum unit, the student has to learn a number of specified skills. The Tutor monitors student progress and estimates the probability of a student's mastery of each skill. Based on this estimation, the Tutor selects new problems that focus on those skills that are not yet mastered. Additionally, the Tutor supports the student by providing immediate error feedback. Hints are given upon request and are provided in a hierarchical way with several levels of detail: through repeated help requests, students receive more and more detailed information, yielding the correct answer. In summary, the Cognitive Tutor Algebra provides efficient help for students as they solve problems and improves their acquisition of procedural knowledge (Anderson, et al., 1995). However, there is concern that the Tutor promotes shallow learning and that conceptual knowledge is not always achieved.

A first attempt to increase the Tutor's impact on conceptual knowledge acquisition was made by Aleven and Koedinger (2002). They integrated a conceptual self-explanation activity in the Cognitive Tutor Geometry, a similar intelligent tutoring system. After each problem-solving step, students were asked to explain their answers by choosing one concept from a list. This activity turned out to speed up their acquisition of problem-solving skills. Unfortunately, the study did not explicitly assess conceptual knowledge gains. Furthermore, since students chose the concepts from a list rather than giving explanations in their own words, it is not clear if they actually gained a deep understanding of these concepts. In fact, as a study by Rittle-Johnson (2006) showed, when students self-explain their own problem-solving, this does not always yield improved conceptual knowledge. In her study, the self-explanations given by students were rather procedural, i.e. students described what they did, but did not reveal explicit thinking about the conceptual rationale.

Conceptual and Collaborative Extension to the Tutor

To improve conceptual knowledge acquisition when learning with the Cognitive Tutor Algebra, I propose to take a two step approach: integrating *conceptual instruction* in the Tutor, and enhancing the Tutor to a *collaborative learning environment*. The first step builds on the initial work by Aleven and Koedinger (2002) and asks students to engage in self-explanation. Following each problem, students are asked to explain mathematical concepts underlying the problem they just solved. In order to remove students' misconceptions that cause faulty problem-solving, students are furthermore instructed to explain incorrect solution steps they made (see also Curry, 2004). Short video clips that are shown prior to problem-solving give examples of fruitful self-explanations and serve to reduce the tendency of students to give descriptive rather than elaborative explanations (see Rittle-Johnson, 2006). As Craig et al. (2000) have shown, observing deep learning processes can in fact influence students' own learning behavior and increases knowledge acquisition. In the second step, conceptual instruction will be combined with collaborative problem-solving on the Tutor. This combination promises to be particularly beneficial: In a collaborative setting, students are more actively engaged in self-explaining (e.g. Chi & Roy, submitted), and explanations given are more elaborative and less descriptive than in an individual learning setting (Teasley, 1995). As a consequence, students' learning is increased. Why do students engage in deeper elaboration when working with a partner? First, giving explanations to a partner feels more natural than giving explanations to oneself (Teasley, 1995). Second, the collaborative setting offers more opportunities for producing elaborative explanations since the receiver of the explanations may point out inconsistencies and require further clarification (Webb, 1989). In turn, the collaborative learning may also benefit from the conceptual instruction as it provides a structure for the interaction. Without support, students often have difficulties to meet the challenges of collaboration (Rummel & Spada, 2005). In a prior study on collaborative problem-solving with the Cognitive Tutor Algebra (Diziol, Rummel, Spada & McLaren, submitted), we found indications that some guidance is needed that the benefits of collaborative learning do unfold. The conceptual instruction can provide this guidance by prompting students to center their discussion around particular questions.

To assess the effect of conceptual instruction and collaborative learning, I will concentrate on a Tutor unit in which students are required to derive a linear equation from a story problem, calculate points, and graph the corresponding line. In these problems, main algebraic concepts such as slope and *y*-intercept are represented in different representational formats (e.g. algebraically and graphically), thus, the unit seems promising to promote conceptual learning. I plan two studies with a 2x2 design (factor 1: procedural vs. procedural plus conceptual instruction; factor 2: individual vs. collaborative learning): a study that assesses the intervention's effect in a controlled laboratory setting, and a field study that validates the findings in a real classroom setting. Students in the control condition will learn with the Tutor in the regular, individual fashion, i.e. instruction emphasizes procedural learning (*individual procedural*). Two experimental conditions aim at independently testing the effects of the two intervention steps. In the *individual conceptual* condition, students will solve problems on their own, but will receive conceptual instruction in addition. In the *collaborative procedural* condition, students will join on one computer to solve problems with the Tutor; however, they will not receive further conceptual support. The third experimental condition will assess the combined effect of collaborative learning with additional conceptual instruction (*collaborative conceptual*). A number of dependent measures will be collected both during instruction and during a post test session. While working on the Tutor, students' problem-solving steps will be saved in log files, and their collaborative dialogue will be recorded to evaluate the learning process. Based on study material used by Rittle-Johnson (1999), post tests will be developed to separately evaluate procedural and conceptual knowledge. I hope that the study results will give further insight of how to promote students' conceptual learning in mathematics alongside with their procedural learning in a computer-based collaborative setting.

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Knowledge Acquisition and Opinion Formation at Science Museums: The Potential of a Discussion Terminal for Collaborative Elaboration on Controversial Issues

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Abstract: This PhD project examines the potential of a discussion terminal to support deep elaboration of controversial information and formation of well-founded opinions at science museums. It is assumed that the salience of controversial information, the opportunity to express one's own opinion, and availability of social comparison information are crucial factors for both learning and opinion formation. A first data collection concerned the impact of active opinion expression and salience of arguments on elaboration processes and knowledge acquisition in a 2x2-design. Results are still outstanding. The second data collection phase will also consider the influence of social comparison information and asynchronous discussion at the discussion terminal.

Science Museums and Public Understanding of Science

Oppenheimer has already stated 1968 (p. 206) that there is an "increasing need to develop public understanding of science and technology" and today, due to rapid growth of new technologies, this need is even bigger than ever before. Informal learning in science museums can be a major contributor in promoting public understanding of science as museums are one central medium in communicating central scientific ideas and presenting relevant objects (Durant, 1992). To promote public understanding of science, multiple viewpoints from different perspectives are needed to be presented (Bayrhuber, 2001): Boyd (1998, p. 214) considers the modern science museum as a "marketplace of multiple points of view, a forum where controversy can be aired". In addressing current socio-scientific issues today, science museums are challenged to present the ambiguity and controversy of these topics and to support visitors in developing reflective and critical thinking (Halpern, 1989). Thus, new installations are needed which emphasize involvement and activity of the museum visitor and put the exhibition content in socially and personally relevant context (McLean, 2006).

Pedretti (2006, p. 30) states that "spaces for dialogue […] enhance the spirit of inquiry, allow for a free exchange of ideas, and encourage the formulation and articulation of carefully thought out, defensible opinions." To create this space, in this project, a computer-mediated discussion terminal was designed to mediate and encourage elaboration on and opinion exchange about the topic nanotechnology as one the most explosive science topics nowadays. Discussion involves the museum visitor in the public debate about science, turns public debate into a personal, "private" one, and should therefore foster reconsideration and reflection of information (Schellens, & Valcke, 2004).

A Discussion Terminal as Scaffold for Critical Thinking and Opinion Formation about Nanotechnology

Critical thinking at science museums refers to visitors' ability to evaluate the evidence for and against New Technologies like nanotechnology, for example. In examining the potentials and risks of new technologies the museum visitor must have "the ability to judge the plausibility of specific assertions, to weigh evidence, to assess the logical soundness of inferences, to construct counterarguments and alternative hypotheses" (Nickerson, Perkins, & Smith, 1985, pp. 4–5). However, as museum visits are leisure activities in most cases and people do not come with a clear learning intention in mind (Falk, & Dierking, 1992), one must assume that visitors do usually not show deep elaboration of exhibit information. But at the same time, this would be an important "learning" goal of exhibit designers and museum curators as our understanding of a good museum has shifted from 'collecting and presenting loose objects' to 'promoting public understanding of science and opinion formation' (Durant, 1992).

The idea of scaffolding systematic and deep processing of relevant information about risks and potentials of nanotechnology to enhance critical thinking and opinion formation of the museum visitors is central to our research: A media terminal has been developed which considers relevant pre-requisites that information processing theories (e.g., ELM, Petty, & Cacioppo, 1986; HSM, Eagly, & Chaiken, 1993) have identified, namely, involvement, and availability of relevant information. Specific cognitive processes are fostered which should lead to deep elaboration on information and belief-based opinion formation. After individual activities, Ss visiting the exhibition 'nanodialogue' have the opportunity to engage in an asynchronous 'debate' about nanotechnology (NT).

Different types of cognitive mechanisms are assumed to lead to deeper elaboration of content when visitors interact with the discussion terminal: *Active participation, involvement and personal relevance*. The discussion terminal increases visitors' involvement by asking for their personal opinion and by challenging this personal opinion by social comparison with others' opinions. Writing down one's personal opinion should result in higher motivation and involvement and also support reflection and abstraction (e.g., Petty, & Cacioppo, 1986). *Salience of multiple perspectives*. A main objective of the discussion terminal is to support bottom-up processes of opinion formation by increased salience of available and relevant arguments from various perspectives. Expert statements are presented as these are regarded as necessary information about NT which is required for critical evaluation of this new technology. To support critical thinking, these expert statements will be rated by visitors with regard to agreement and relevance. This should help to identify relevant attributes of NT and should therefore scaffold belief-based, thoughtful opinion formation. *Social comparison information and opinion exchange.* Social influences on individual opinion formation and information processing will be regarded in our research as according to social comparison theory people tend to evaluate their own opinions by using similar others as models (Suls, Martin, & Wheeler, 2004). The discussion terminal raises new possibilities to support communication and debate between visitors - independent from their time of visit. Therefore, this research project will consider the impact of reported opinions of other visitors on individual cognition.

Research Method

A study was designed to investigate whether a discussion terminal supports deep elaboration of controversial information and formation of well-founded opinions. It is assumed that salience of information, opportunity to express one's own opinion, and availability of social comparison information are crucial factors for learning and opinion formation. The impact of these three independent variables on elaboration processes and knowledge acquisition will be tested in a 2x2x2-design.

A "virtual museum" about NT is used which is based on a real exhibition about NT which informs citizens about both facts about nanotechnology and its potentials and risks. It contains quite a number of relevant expert statements which comprise different arguments both in favour of and against NT.

160 participants are randomly assigned to eight conditions (cp. table 1). They explore the exhibition without constraints and time pressure. Afterwards, they interact with the discussion terminal: In the condition of salience of arguments but without active expression of their opinion, participants assign eight statements to corresponding experts (cond. 1). A second group rates NT in general as either "I am in favour NT" or "I am against NT" and types an own statement into the discussion forum (cond. 2). The third group additionally evaluate eight expert statements by 'persuasive power' and 'relevance' before rating NT in general (cond. 3). The control group works on a NT-quiz. On condition of active expression of opinion, feedback about others' opinions is available after individual rating activity. This feedback is experimentally faked and systematically varied as consistent (cond. 4/5) or conflicting with Ss' own opinion (cond. 6/7).

During exploration of the exhibit website, all activities of the participants are retained as log file-data. As exploration of the exhibition takes place without any instructions or constraints, this data are relevant to assess which information was gathered during the 'museum visit'. Knowledge acquisition is assessed by means of a short knowledge test, containing nine questions on nanotechnology, ranging from simple factual knowledge to more transfer knowledge which requires drawing of inferences. Additionally and even more interesting is acquisition of *attitude relevant knowledge*, that is relevant arguments in favor or against nanotechnology from a variety of application areas and perspectives (medicine, military, society, economics). This knowledge is assessed by means of instruction to list all arguments the participants can remember from the exhibition and to write down a short summary. This summary of participants' personal impressions about NT will be analyzed with regard to indicators of critical thinking and awareness of controversy. Participants' attitudes towards nanotechnology and new technologies in general are assessed by attitude profiles.

Table 1: Research design.

		Active expression of opinion			
		no	yes		
			Social comparison information		
			neither	consistent	conflict
Salience of arguments	no	control group	condition 2	condition 4	condition 6
	yes	condition 1	condition 3	condition 5	condition 7

Expected Impact on Knowledge Acquisition and Opinion Formation

It is assumed that salience of controversial information, possibility to express one's own opinion, and social comparison information are all crucial factors for both learning and opinion formation. Based on theoretical considerations, it can be assumed that salience of arguments and opinion expression are crucial factors for learning and opinion formation. Elaboration of information should be deeper when both factors are implemented. Participants of condition 3 should therefore gain most knowledge, remember more relevant arguments and have more sophisticated opinions about nanotechnology. Salience of arguments should have an effect on attitude relevant knowledge remembered and also on perceived ambivalence and difficulty to evaluate nanotechnology. This should results in less extreme but more stable attitudes. An indicator of information integration would be response time at the overall rating, too. Participants of the control condition (who solve a quiz about nanotechnology) should recall more factual knowledge about the exhibition as they have the opportunity to deal with items from the knowledge test already at the opinion terminal, and they also get feedback about right answers to these questions. Social comparison information and opinion exchange should further stimulate elaboration of arguments and evaluation of visitor's own opinion, especially if a cognitive conflict between one's own opinion and others' opinions is elicited. This conflict should elicit further activities at the discussion terminal and within the exhibition. Visitors might, for example, read through others' statements to learn about their arguments ("*Why* do they think that?").

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The Effects of Knowledge Awareness on Peer Interaction and Shared Mental Model in CSCL

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Abstract: The primary focus of this research is to investigate the effects of awareness on collaborative learning process and product. In face-to-face settings, people are naturally aware of, maintain, and update the information of peers' activities. But, in case of the distributed environment, learners have difficulties in acquiring the awareness of people and their activities. In consequence, providing awareness information is crucial for sustaining effective group interaction and performance in the distributed learning environment.

Introduction

The I-P-O(the Input-Processes-Output) framework has been used as a team learning mechanism in an organization(Ilgen, Hollenbeck, Johnson, & Jundt, 2005). Also, this framework could be regarded as the collaborative learning mechanism. This mechanism has three key elements as followings. Firstly, input is the information about participants' activities in learning space. Secondly, process is a peer interaction during collaborative learning. Finally, output is the group product which results from sharing each other's mental models. Because of the physical distance among participants in CSCL(Computer-Supported Collaborative Learning) environment, learners are not aware of peers' activities; to be more specifically, the peer-related 5W1H(who, what, when, why, where, how) information in collaborative space(Dourish, 1997).

To more active interact each other and to achieve a higher performance in CSCL, they require knowing 5W1H information. Specifically, this study focuses on 5W1H information about peers' knowledge. For learners, it is not easy to get realized peer's knowledge until it is externalized. Perceiving the externalized peer's knowledge is called *the knowledge awareness*. To investigate the effects of knowledge awareness in CSCL, the research questions are:

(a) Does knowledge awareness foster peer interaction?
(b) Does knowledge awareness affect building the shared mental model?

Theoretical Framework

Awareness as Group Input

The purpose of CSCL systems is the building the knowledge of the collective(Stahl, 2006). To build collaborative knowledge, learners could primarily be aware of each other's knowledge(Kirschner & Kreijns, 2005). Knowledge awareness is a kind of awareness. *Awareness* is "a knowing what is going on and(or) what happened"(Endsley, 1995) or "an understanding of the activities of others"(Dourish & Bellotti, 1992). Specifically, *knowledge awareness* is defined as the state of understanding the knowledge-related activities of the peers(Ogata, 1998) and could be visualized as the knowledge structure(Keller, Tergan, & Coffey, 2006). The CSCL systems should provide learners knowledge awareness support tool enabling to be aware of the current status and history of peers' knowledge.

Coordination, Cooperation and Communication (3C) as Group Processes

The 3C model is one of the collaboration system(i.e. Computer-Supported Cooperative Work) development methodologies(Lucena, Fuks, Raposo, Gerosa, & Pimentel, 2006). According to the 3C model, a group interaction is initiated by awareness and it consists of *coordination*, *cooperation* and *communication*(Ellis, Gibbs, & Rein, 1991; Gerosa, Fuks, & Lucena, 2003).

First 'C'(Coordination) means the integration of group operations at the appropriate times and in a timely way. Second 'C'(Cooperation) involves the interaction between participants in shared object. Last 'C'(Communication) refers to co-construction of meanings. Put briefly, awareness is located at the central position in coordination for the consistency of the joint work, cooperation for operating the shared object among the participants and communication for building common ground.

Coordination

The interdependent tasks performed by group members must be coordinated; that is, group operations must be synchronized in a timely way, in the correct order, at the right time and with appropriate people(Eccles & Tenenbaum, 2003). In order to be appropriately taken the coordinated behaviors, members need to be aware of others' operations(what they are going to do, when they are going to do, and so on.). The coordination can be classified into pre-process, in-process and post-process. The pre-process coordinated action means the planning prior to performance. The plan involves creating overtly scripted roles and responsibilities(the intended courses of action). Learners focus on performing their assigned actions. The in-process coordination includes the managing collaborative process and making or adjusting of plans during performance. Learners are required to update group members and tasks of any change. In post-process coordination means the evaluation after performance. Learners evaluate their coordination problems and establish possible solutions.

Cooperation

Cooperative behavior means the joint work of group members to complete assigned tasks. In cooperation, participants focus on a shared object, divide the task into sub-tasks hierarchically or heterarchically, solve sub-tasks independently and then put together the partial results into the final group output(Dillenbourg, Baker, Blaye, & O'Malley, 1996; Gerosa, Fuks, & Lucena, 2003).

Communication

Communicative interaction is often referred to as a grounding(Baker, Joiner, Traum, & Hansen, 1998). Communication is an inter-active process that allows people to construct and maintain common ground. In communication, learners constantly try to ground that what their peers say has been understood. When learners communicate with peers, they share progressively each other's mental model, negotiate their different perspectives and co-construct their own mental model by grounding. Levels of grounding are accessibility, perception, understanding and agreement(Baker, Joiner, Traum, & Hansen, 1998; Dillenbourg, Traum, & Schneider, 1996).

Figure 1 shows that group process, collaborative knowledge building process, is iterative from coordination in knowledge acquisition phase to communication in knowledge creation phase.

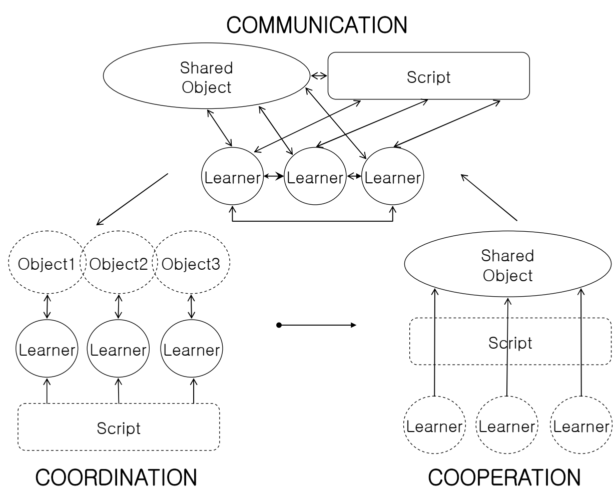

Figure 1. 3C as Group Processes: Adapted From Engestrom et al., (1997, pp. 372-373).

Table 1 shows the phases of collaborative learning, 3C and its characteristics.

Table 1: The Phase of Collaborative Learning and 3C: Adapted From Engestrom et al., (1997).

Phase	3C	Characteristics	
		Scripted Role	Object
Knowledge Acquisition	Coordination	Fixed	Not Shared
Participation	Cooperation	Fixed	Shared
Knowledge Creation	Communication	Not Fixed	Shared

Shared Mental Model as Group Output

In collaborative learning, team members share knowledge of taskwork and teamwork for accomplishing the common goal. The more interactive the team is, the more similar in content/structure the knowledge of task-related process and of its teammates are(Cannon-Bowers & Salas, 2001). Throughout group processes, the team leads to produce the *shared mental models*. These models are viewed as the mental representations commonly held by group members that enable themselves to explain and expect the taskwork and teamwork(Fiore & Salas, 2004).

Figure 2 shows group input(knowledge awareness), group process behaviors(coordination, cooperation, communication) as developmental trajectories and group output as theoretical framework in this research. To learn together each other, participants are required to be aware of others' activities. Knowledge awareness information enables members to generate more accurate expectations about the behaviors of the others, more collaborative interactions and more effective performance. This study is based on a comprehensive theoretical framework depicted in figure 2.

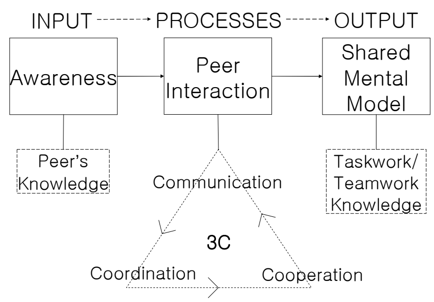

Figure 2. Theoretical Framework.

Method

Participants and Instruments

The preliminary study was taken in the course for pre-service teachers in a university in South Korea. Pre-service teachers(N=38) enrolled for the course 'Methodology & Technology of Education' during the fall 2006. As a course requirement, they are required to form groups to work on an assignment during an 8-week period in the CSCL environment. Each group included 2 students. The participants was randomly divided into an experimental group(with knowledge awareness scaffold) and a control group(without knowledge awareness scaffold).

The experimental environment consists of CSCL systems and a knowledge awareness scaffold. The CSCL environment consists of chatting, bbs, announcements, calendar and so on. Dyads of students coordinate, cooperate and communicate on their individual computer with the online shared space. A knowledge awareness scaffold(in this research, ThinkWise is used) supports peers' knowledge by visualizing their knowledge structure(See Figure 3).

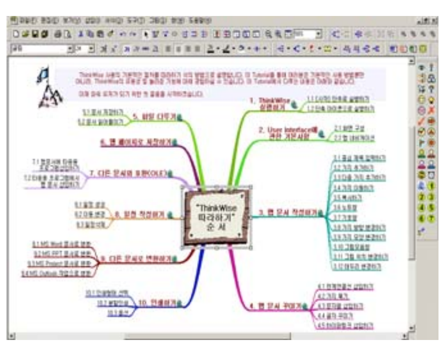

Figure 3. Knowledge Awareness Scaffold.

Procedure

Participants in the study attended three sessions. In the first session(the learning phase), dyads learned Gagne's instructional design model in CSCL environment and made a plan for their task process. Simultaneously, each dyad discussed roles and responsibilities(R & R) definition of an instructional designer and a subject matter expert and assigned R & R. In the second session(the basic application phase), they designed collaboratively instructional materials applying the principles that they had learned in the previous session. In the third session(the advanced application phase), they elaborated their group work. Both experimental groups and control groups collaborated synchronously using the chatting function provided in CSCL environment. But only experimental groups could externalize their knowledge structure with a KA scaffold in each session and exchange their knowledge awareness information within the dyad.

Experimental Design

Independent Variable

The independent variable is the support of knowledge awareness. We hypothesize that the support of knowledge awareness will contribute to effective collaborative learning processes and outcome in CSCL. To identify our assumption, we provided 10 experimental groups with KA scaffold and didn't 9 control groups.

Dependent Variable

The dependent variables are the levels of group processes(communication, coordination, cooperation) and products(taskwork/teamwork knowledge). These data will be analyzed by following methods (see Table 2).

Table 2: Data Analysis Method.

	3C	Category	Sub-category	Method
Group Process	Coordination (Eccles & Tenenbaum, 2003)	Pre-coordination	Planning(Roles & Responsibilities, Schedule)	Chat log analysis
		Process-coordination	Managing process	
			Revising previous plan	
			Creating new plan	
		Post-coordination	Evaluating coordination breakdown	
	Cooperation (Gerosa, Fuks, & Lucena, 2003)	Focusing on a Shared Object	-	
		Splitting Task into Subtask	Hierarchy (Independent Task)	
			Herterarchy (Interwined Task)	
		Solving sub-tasks	-	
		Assembling Results	-	
	Communication (Dillenbourg, Traum, & Schneider, 1996)	Accessibility	-	
		Perception	-	
		Understanding	-	
		Agreement	-	
Group Product	Shared Mental Model	Taskwork Knowledge	-	Questionnaire (Kang & Yang, 2003)
		Teamwork Knowledge	-	Questionnaire (Lim & Klein, 2006)

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Acknowledgments

This study was supported by Korean Ministry of Education BrainKorea21 Project of 'Emerging e-Learning Research & Development' for the year 2007.

Trajectories of Collaborative Scientific Conceptual Change: A Classroom Study in a CSCL Environment

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Introduction

The proposed study aims to achieve two goals. First, it attempts to establish a new theory – the collaborative scientific conceptual change theory, which explicitly attends to social factor and epistemic practices of science; second, it will report the findings of a classroom study to test the new theory and provide pedagogical implications for promoting student scientific thinking by investigating the trajectories of conceptual change in a computer-supported collaborative learning (CSCL) environment. The following discussion outlines the theoretical framework, research questions, the methodology, and the contribution and significance of the proposed study.

Theoretical Framework

Some conceptual change theories stress the effect of cognitive discrepancies following Piaget's disequilibrium theory (Chinn & Brewer, 1993; Posner et al., 1982; Thagard, 1992) However research has shown that adults, children and even trained scientists fail to change their theories when they face conflicting evidence (Kuhn, 1989). There are at least two additional factors involved in fostering conceptual change: the social interaction and the epistemic practices of science. Peer discourse may create an awareness of the need for knowledge revision, stimulate knowledge reconstruction, and encourage deep processing, thus leads to convergent conceptual change (Roschelle, 1992). The elements in valued epistemic practices like testing and modifying ideas by experimentation and evidence-based argumentation may foster conceptual change. In the new conceptual change model, I emphasize the effect of social factor and epistemic practices as well as the mutually influential relationship between them. *Collaborative scientific conceptual change* occurs when learners co-construct knowledge and shift to valued epistemic practices of science involving systematic observation, collaborative argumentation, and scientific experimentation. To testify this new theoretical model, I am proposing the following study in which middle school students inquire knowledge about a complex system – the aquarium ecosystem, in a CSCL environment.

Research Questions

This study will test the collaborative scientific conceptual change theory by examining the relationships between the patterns of collaborative discourse, the epistemic practices, and the trajectories of collaborative scientific conceptual change. Specifically, I intend to address the following research questions:

1. How do students' conceptions change as a result of participating in a technology-enhanced curriculum unit for learning about aquarium ecosystem?
2. Does convergent conceptual change occur during the collaborative activities? If so, what are the relationships between the collaborative discourse patterns and process of the convergent conceptual changes?
3. Is there any change in student epistemic practices during the collaborative exploration of the computer simulations? If so, what are the relationships between the epistemic practices and the process of convergent conceptual change
4. What are the trajectories of students' collaborative scientific conceptual change?

Research Design

Materials – RepTools toolkit

The RepTools toolkit[1] uses multiple representational tools to provide support for student learning, which includes a function-oriented hypermedia and two NetLogo (Wilensky & Reisman, 2006) simulations. The hypermedia introduces the aquarium system with a focus on the functional aspects and provides linkages between the structural, behavioral and functional knowledge. By exploring this hypermedia, students can construct a basic understanding of the system and use it as a reference for interpreting the simulations. It also includes two simulations at different scales – the fish spawn model and the nitrogen cycle model. The fish spawn model is a macrolevel simulation displaying how fish spawn in a natural environment. It helps students investigate the

[1] This project was funded by an NSF CAREER grant # 0133533 to Dr. Cindy E. Hmelo-Silver. The RepTools toolkit design is part of the project. I am one of the principal designers.

relationships among different aspects of an ecosystem, such as the amount of food, water quality, and fish population (see figure 1). The nitrogen cycle model presents how chemicals reach a balance in the aquarium at a micro level. It allows students to examine the bacterial-chemical interactions that are critical for maintaining a healthy aquarium (see figure 2). In both simulations, students can adjust the values of variables, observe and discuss about the results. The two simulations were designed to help students make connections between the macroscopic substances that students study and the aperceptual microscopic entities and underlying processes.

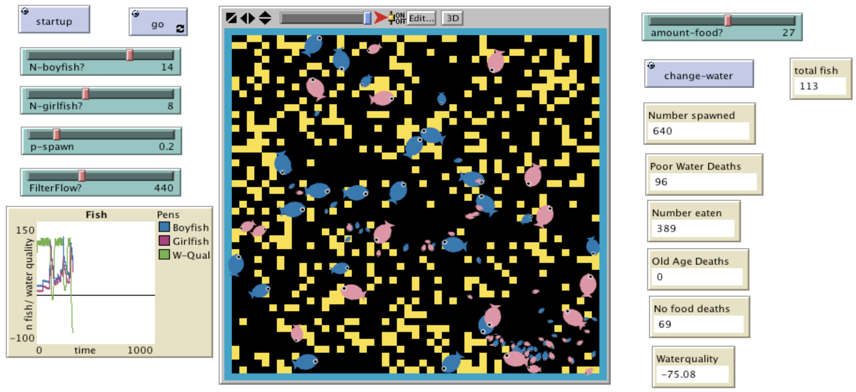

Figure 1. Screenshot of the Fish Spawn Simulation.

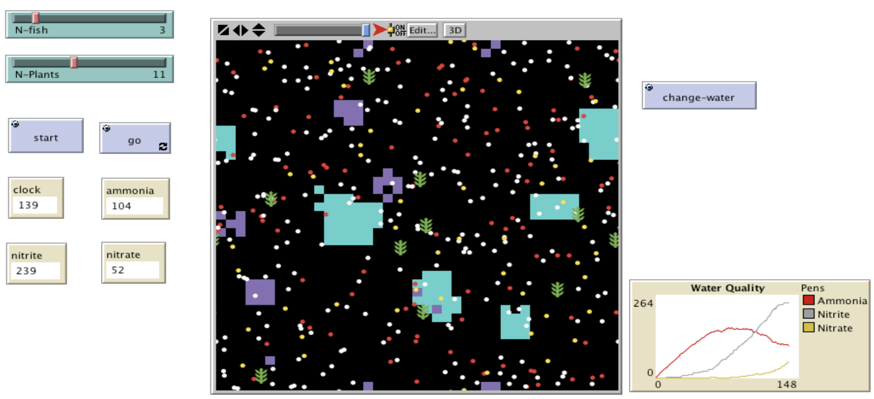

Figure 2. Screenshot of the Nitrogen Cycle Simulation.

Participants and Procedures

The participants are 145 seventh and eighth graders from two public schools taught by two teachers. The study was conducted as part of the regular science instruction. Before the classroom study, both classrooms had a physical aquarium model installed and maintained for about two months. All learning activities were completed in small groups, which varied from 2 to 6 students. The students explored the hypermedia software in groups followed by class discussions and construction of concept maps that connected parts of the system to their function. Then students were introduced to the NetLogo environment and collaboratively explored the two simulations. All students took an individual pre- and posttests. In all class periods, two focal groups were video and audio taped. There are a total of 20 focal groups available for analysis. The proposed study will focus on their collaborative group exploration of the simulations.

Coding and Analyses Plan

Currently the data collection has been completed. I am at the stage of transcribing data and developing coding schemes. My goal is to complete the dissertation writing by May, 2008. The coding and analyses of the pre- and posttests will address the first research question and investigate the learning outcomes. The coding and analyses of the video/audio data will address the remaining three research questions and investigate the learning process.

The pre- and posttest data. Grounded categories will be identified for the purpose of developing a coding scheme for identifying ideas presented in the tests. This coding scheme will also adapt an SBF-based coding scheme (see details in Hmelo, Holton, & Kolodner, 2000) to judge the depth of understanding in the pre- and posttests. The purpose of the coding scheme is to capture the individual conceptual change demonstrated in the written assessment. Repeated measure analyses will be applied to compare the coded concepts identified from the pre- and posttests.

The video/audio data. Both the verbal and nonverbal data will be transcribed verbatim. The transcriptions will be coded in two passes. The first pass will divide the transcribed conversation into episodes marked by switches in the concept of a discussion. A conceptual change coding scheme will be developed to capture the level of conceptual understanding within each episode. The purpose of this coding scheme is to capture trajectories of group conceptual change as students were engaged in understanding: (1) the representations, (2) the relationships among the representations, and (3) the connections of the two simulations. In the second pass, each episode will be divided into segments that consist of different discourse functions. A collaborative discourse coding scheme will be developed including categories like agreement, disagreement, questions, negotiation, observation, reference, setting goals, proposing a hypothesis, testing hypotheses, warranting claims, note taking, summarizing, to identify the cognitive and metacognitive aspects of the discourse as well as students epistemic practices. The validity of the coding schemes will be achieved by reference to related literature and consultation with experts. Interrater reliability of the coding will be obtained. Once the coding schemes are shown to be valid and reliable, I will be the principal rater to finish coding all the transcriptions. Then the data as well as the codes will be imported into MEPA (The Multiple Episode Protocol Analysis; Erkens, 2005) to reveals how certain types of interactions followed by others more often than what one would expect by chance. I will use sequential analyses techniques to investigate what kind(s) of collaborative discourse patterns and epistemic practices that leads to the collaborative scientific conceptual change.

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Goal-Awareness and Goal-Adaptive Information Presentation to Support Collaborative Learning in Informal Settings.

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Abstract: This dissertation explores the use of adaptive technology for more goal-oriented learning in informal settings like museums or web sites. Visitors usually do not give priority to learning and knowledge building. It is assumed that information presentation should be adaptive and match visitor dyads' shared interests to enhance collaborative elaboration on presented information in these settings. During collaborative exploration of a site, awareness of shared goals and goal-oriented knowledge communication should further enhance learning. To address these questions two empirical studies are conducted. Exhibit information is presented adaptively to visitor dyads' shared interests during their visit to a virtual (study 1) and a real museum (study 2). Impact on visitors' conversation, behavior and learning can provide further perspectives for future research and provide deeper insights on collaborative knowledge processing and on design of technology in informal settings.

Theoretical framework

Informal learning settings like museums or web sites provide rich resources for individual and collaborative knowledge building: Visitors can choose from a huge pool of information according to their personal interest (*free-choice-learning*, Dierking, Ellenbogen, & Falk, 2004). Therefore, visitors' interests and learning goals have an even greater impact in informal than in formal learning settings (Boekaerts, & Minnaert, 1999). For example, they guide information selection, evaluation of and elaboration on information during a visit. Unfortunately, informal learning is often inferior to formal learning with regard to knowledge acquisition. This seems to be due to two different facts: A lack of goal-orientation and a reduced amount of invested mental effort.

First, as museums are leisure settings many visitors come without any or without concrete learning intentions in mind (Black, 2005; Packer, 2006). However, different amounts of knowledge are gained by visitors with different visiting intentions (Falk, Moussouri, & Coulson, 1998; Packer, 2006). Visitors with a focused visiting strategy learn more from their museum visit (Falk et al., 1998). Therefore, learning could be improved when a museum is visited in a more focused way. Studies in formal learning contexts showed the relevance of goals for more strategic information processing (e.g., Zumbach, & Reimann, 2002). Conscious goals are available in working memory and have a high potential to structure information processing (Austin & Vancouver, 1996). Additionally, aware goals can raise curiosity, intrinsic motivation and attention towards reaching this goal (Boekarts, & Minnaert, 1999; Csikszentmihalyi, & Hermanson, 1995; Loewenstein, 1994). Therefore making goals aware to visitors prior to a museum visit might enhance their goal orientation and thereby informal learning.

Second, people invest less mental effort in leisure settings than in formal learning settings (Salomon, 1984). Additionally, visitors' attention decreases with visiting time (Serrell, 1997). But due to lack of structure and pre-selection of information, informal settings often require even more mental resources to process information thoroughly (Boekaerts, & Minnaert, 1999). For example, advanced organizers (Falk, 1997) or conversation with others (Leinhardt, Crowley, & Knutson, 2003) can help visitors to process information in informal settings. But these actions do not serve all visitors in the same way: They have different interests, prior knowledge, and time resources. New media applications can adapt information to visitors' needs. An exemplary museum application is a PDA guide suggesting tours based on visitors' interests and time budget (Teo, 2005). As information that matches visitors' interests reduces the amount of mental effort needed, more cognitive capacities are available to process the information. Thereby, informal learning could be increased.

Descriptive museum studies (e.g., Black, 2005, p. 16) show that about 80 % of museum visitors come in groups. Co-visitors influence knowledge processing in the museum (Packer, & Ballantyne, 2005): Dyads share opinions about the exhibits, explain them to each other and relate information to prior shared experiences in their conversations. Therefore, the social situation can assist knowledge acquisition in the individual (e.g., Hinsz, Tindale, & Vollrath, 1997) and should be taken into account when designing technological support for informal learning.

Research Questions

First, the research question is addressed, whether awareness of a visitor dyad's shared goals influences visitor dyad's goal-orientation during informal learning in a museum. Therefore, visitor dyads in this study are asked to state their shared interests prior to the visit of the exhibition. It is assumed, that increased goal-orientation results in more focused exhibit selection, influences conversation, and gives rise to learning.

Second, it will be investigated whether adaptation of exhibit information to a visitor dyad's shared goals can further support elaboration of information (conversation, exhibit selection) and learning. For this purpose an adaptive technology is used, that provides visitor dyads with adaptive information according to their shared interests on every selected exhibit. This adaptation reduces the requirement to connect selected objects and information with a dyad's shared goal. It is assumed that visitor dyads provided with adaptive information will select objects differently, elaborate information in their conversation in different ways, and finally learn more than visitors provided with non-adaptive information.

A third research question addresses the comparability of different research settings and their impact on validity, reliability, and authenticity of studies on informal learning in museums. An exhibition about nanotechnology ("Nanodialogue" by the European Commission, cp. Nanodialogue Consortium, 2007) serves as research setting in this project. It will be used in three different versions: As a virtual exhibition on the web (study 1: adaptive graphical hypertext), as a physical exhibition in the lab (study 2: adaptive PDA), and as a physical exhibition in the real museum (study 3: adaptive PDA).

Methods

A 2 (goal-awareness, no goal-awareness) x 2 (adaptive, non-adaptive) experimental design is used in these studies (cp. table 1). 15 dyads of acquaintances per condition are asked to participate in a study on communication in museums (cover story).

Table 1: Research design

	Goal-adaptive Information	
Goal-awareness	yes	no
yes	condition 1	condition 2
no	condition 3	control condition

At the beginning, participants are familiarised with navigation in the graphical hypertext (study 1) or use of the PDA (study 2). Dyads in the goal-awareness conditions are asked to select a topic of shared interest from a list of topics, which are satisfied in the exhibition. In condition 1, information about the exhibits is adapted to these interests. In condition 3, information about the exhibits is adapted implicitly to a dyad's behaviour in the first minutes of their visit. While dyads visit the virtual exhibition without time constraints, their conversation, exhibit, and information selection is recorded. After the visit participants are asked to fill out a questionnaire on their knowledge, satisfaction, experienced mental effort, prior knowledge, and interest in the topic.

Analyses

Qualitative and quantitative analyses will be combined in this dissertation: Information selection during the visit will be traced by the PDA's (study 2) or hypertext (study 1) log files and will provide data on the selection of exhibits and information, time spent at exhibits, and overall visiting time. Visitors' dialogues will be analysed with respect to shared goal and information selection, information evaluation, and conversational elaboration.

Comparisons between the four experimental conditions will provide insight into the influence of goal-awareness and goal-adaptive information presentation on information selection, conversational elaboration and knowledge acquisition during an informal museum visit. By comparing the laboratory and the virtual museum setting, knowledge is gained about differences in goal-oriented learning in a real-life and a virtual informal setting. Furthermore, both settings will be compared to the real museum setting to ensure external validity of findings gained from the two laboratory experiments.

Expected Results

Visitors focused on a specific interest stay longer in a museum (Doering, & Pekarik, 1997; Falk et al., 1998) and learn more (Falk et al., 1998). By adapting information to visitors' shared interests a deeper processing strategy should be induced. Therefore, it is expected that information is elaborated deeper in dyadic conversation, when information is adapted to their shared interests. Dyads with non-adaptive information should gain broader, but shallower knowledge whereas dyads with adaptive information should acquire more detailed, more elaborated knowledge; this same pattern should show up in the knowledge test. It is assumed that dyads in condition 1 are more satisfied with their visit, need to invest less mental effort, and get more interested in the topic.

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Acknowledgements

The author is member of the Virtual PhD-Program "Knowledge Acquisition and Knowledge Exchange with New Media" (VGK) sponsored by the German Research Association (DFG). This dissertation is conducted within the wider context of a research project (Knowledge Media Research Center, Tübingen; Deutsches Museum, Munich; Institute for Science Education, Kiel) on learning in the museum with new technologies funded by the "Pact for research and innovation" of the German Federal Ministry of Education and Research.

Mapping the Edublogosphere: Implications for Literacy and Teacher Professional Development

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Abstract: New Internet and communication technologies (ICTs) facilitate collaboration and professional development among teachers. This qualitative case study examines how one teacher develops her "teacher identity" through blog posts written throughout her first year of teaching. Using a new literacies perspective, this study also seeks to describe how teachers use the tools afforded by new ICTs. Data consists of the sociolinguistic multimodal narrative blog posts made by a new teacher throughout the 2006-07 school year. Anticipated findings from this study include themes of pedagogy, classroom management, and role of the blog in teacher development.

Introduction

Internet and communication technologies facilitate new forms of collaboration and interaction that continually impact our understanding of what it means to be literate. A direct correlate of this phenomenon relates to how teachers use these emergent tools to support literacy instruction and to construct professional identities online. Many researchers argue that it is time to expand our understanding of what it means to be literate within the current context of economic and technological globalization. In his book *Literacy in the New Media Age*, Kress (2003) states that "it is no longer responsible to let children experience school without basing schooling on an understanding of the shift from competent performance to design as the foundational fact of contemporary social and economic life" (p. 37). This shift in our conception of literacy and the cultural reproduction fostered by public education underscores the importance of designing learning environments that facilitate critical thinking, social interaction, and situated learning (Voithofer, 2005). This shift both represents and embodies the new literacies.

Purpose of the Study

The purpose of this narrative case study is to explore the experiences of new teachers who chronicled their first-year experiences in a blog. The nascent intellectual online space occupied by bloggers, often referred to as the *blogosphere*, provides a rich context for thinking about new teacher development. This study seeks to examine how new teachers use blogs to support their literacy instruction and to develop their conception of literacy, as well as how the blogs address and contribute to the construction of a specific *teacher identity*. For the purposes of this study, the *edublogosphere* will be defined as the online space in which bloggers concerned with educational issues (from classroom practices to federal policy critiques) contribute, consume, debate and produce content, from personal narratives to persuasive political arguments. The public nature of blogs, accessible to anyone through the Internet, and their potential for facilitating interaction via comments, email and open-access make them a unique venue for analyzing teacher identity development through narrative reflection. Findings from this study will shed light on the process of teacher induction, providing teacher educators and researchers with new insight on the process of construction and representation of a professional identity among first year teachers.

The public nature of teacher-created blogs foregrounds the often silenced voice of the classroom teacher and provides a first-hand account of current issues concerning teachers. The variety in content and purpose among teacher-created blogs warrants further examination. Ray and Hocutt (2006) point out that "identifying the parameters of this population [blogging teachers] and tracking its growth is critical for future research in this area" (p. 12). By analyzing the narrative reflections of a new teacher using the sociolinguistic, multimodal texts of her blog posts (Chase, 2005), I seek to inform current understandings of the process of teacher preparation and development (Darling-Hammond, 2006; Kauffman, Johnson, Kardos, Liu, & Peske, 2002; V. Richardson, 1996), the construction of digital identities (Farmer, 2006), and the notion of blogs as a distinct, multimodal genre (Bateman, Delin, & Henschel, 2007; Burgess, 2006; Herring, Scheidt, Bonus, & Wright, 2004), with structural narrative features that facilitate meaning-making, knowledge-building, and identity-construction (Ferdig & Trammell, 2004; Knobel & Lankshear, 2006). By incorporating new literacies through the use of blog posts as data to inform our understanding of how new teachers develop and learn throughout their first year, this study contributes to the emergent body of research at the intersection of technology and literacy as it relates to teacher preparation (Chandler-Olcott & Mahar, 2003; Godwin-Jones, 2006; Hobbs, 2006; Kinzer, Cammack, Labbo, Teale, & Sanny, 2006; Labbo, 2006; Leu, 2000; C. Luke, 2003; Reinking, 1998; Swenson, Rozema, Young, McGrail, & Whitin, 2005).

From this theoretical orientation, I will address the following research questions:

R1: What are the structural and functional components of a teacher-created blog? How do these components shape the teacher's understanding and use of new literacies?

R2: How does the teacher-created blog address the new literacies afforded by the Internet?

R3: How does the teacher-created blog account for online professional identity construction and representation for educators?

The nature of literacy is shaped by the sociocultural context in which literacy events and practices take place. Notions of learning, knowledge, and meaning-making shift as cultural events influence what society deems valuable. The sociocultural theoretical underpinnings within the New Literacy Studies encompass the sociolinguistic work of Gee's "big D" discourses (Gee, 1996, 2004, 2006), the socioliteracy work of Lankshear and Knobels' analysis of blogs and memes (Knobel & Lankshear, 2005; Lankshear & Knobel, 2004, 2006), the critical literacy work of Luke and Freebody's conception of the emancipatory power of literacy (Luke, 2000; Luke & Freebody, 1999), and Street's development of social literacies (Street, 1984, 1995). Street (2006) reflects on the history of this line of research. "What has come to be termed 'New Literacy Studies' refers to a body of work that for the past twenty years has approached the study of literacy not as an issue of measurement or of skills but as social practices that vary from one context to another" (p. 21).

Methods

Criteria for Blog Selection

The present study seeks to develop a "language of description" (Street, 2006) for the emergent edublogosphere. To begin this process, I will establish a corpus of teacher-created blogs based on criteria from the research literature (Herring, Scheidt, Bonus, & Wright, 2004; Miller & Shepherd, 2004), as well as on my own experiences as a participant in the edublogosphere . Guiding considerations for establishing a comprehensive, coherent corpus are based on the following criteria:

- Authorship – first-year teachers; graduates of teacher education programs
- Structure – for purposes of tracking developmental trajectories, selected blogs contain an average of 1-2 posts per week during the 2006-07 school year (frequency of posts)
- Content – blogs selected that specifically address issues of teaching (relevance to education and literacy)

Participants

Participants will be selected based on the criteria listed above, primarily first-year teachers who graduated from traditional teacher education programs and blogged consistently throughout their first year of teaching. At this stage of the research, one blog has been identified for further narrative analysis.

Data Collection Methods

Data sources for this study are the content and structural features of blogs written by first-year teachers during the 2006-2007 school year. Purposive sampling of first-year teacher blogs will be conducted in order to learn about the experiences of new teachers in their own words. Following the tradition of naturalistic inquiry, blogs will be identified through various Internet search engines (e.g., Google, Technorati, Yahoo) using the search terms *first-year teacher blogs*, *new teacher blogs*, and *beginning teacher blogs*. Prospective blogs will be screened according to the criteria listed above (authorship, structure and content). Using narrative analysis (Chase, 2005), I will identify patterns of meaning in the data to provide a qualitative description of themes within the narrative blog content.

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Bridging: Sustaining online, collaborative knowledge building over time and across collectivities

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Motivation

Collaborative learning and knowledge building that take place in small virtual groups and in online communities require that co-participants "*bridge*" multiple elements of their interactions over time and across diverse collectivities—a non-trivial and possibly very consequential undertaking. Although *continuity* and *sustainability* are critical aspects of successful knowledge building, these aspects of the interdisciplinary study of computer-supported collaboration are not yet well understood from an *interactional perspective*. As CSCL researchers and designers, we need to better understand how interactions which are dispersed over time (e.g. long-term projects, multi-session problem-solving engagements, etc.) and which cut across different collectivities (e.g. sub-groups, teams, etc.) can be interlinked or "*bridged*" so that they lead to the successful development of collective knowledge over time. The *interactional bridging activity* necessary for *continuity* and *sustainability* of collective knowledge building can be characterized as a set of methods through which participants deal with the discontinuities of their joint activity, such as those emerging from multiple problem-solving perspectives, multiple interactional episodes over time, and multiple participants. Bridging thereby might tie meaning making at the local small-group unit of analysis to interactions at larger units of analysis (e.g. online communities, multi-team collectivities, etc.).

Research Questions and Scope

This research investigates, from an *interactional perspective*, the ways in which bridging methods exhibited by small groups participating in the Virtual Math Teams (VMT) community —an online learning community of K-12 mathematics— contribute to the *continuity* in their collaborative knowledge building. As part of VMT, small virtual teams of secondary students distributed across the U.S interact synchronously through a collaboration environment to solve open-ended mathematical problems over a series of online sessions. In addition, they share their work asynchronously with other virtual teams engaged in similar problem-solving activity. In this context, we will pursue the following three goals: **(a)** Defining *how* three different aspects of the online interactions of virtual collaborative learning teams are bridged: *episodes*, *collectivities*, and *perspectives*; **(b)** Exploring the *interactional effect* of such bridging activity on the sustained knowledge work of virtual learning teams; and **(c)** Investigating how such bridging activity can be *supported* by designed artifacts. Correspondingly, we propose the following three research questions:

Q1. What are the *interactional bridging methods* that can be identified in the VMT online learning sessions? How can we effectively conceptualize these phenomena and analyze their *interactional effects*?

Q2. How does bridging activity span across the individual, small group and community (cross-group) levels of knowledge building activity?

Q3. How should online environments and associated activity systems (tasks, resources, scaffolding, etc.) be designed to promote bridging and take advantage of it?

Theoretical Framework

We base our theoretical framework on the views of the *situative perspective* (e.g. Greeno, 2006) and the theory of *group cognition* (Stahl, 2006a), which see the organization of action as an emergent property of moment-by-moment interactions among actors, and between actors and the *activity system* in which they participate collectively. Because of this, we focus on understanding activity and changes in the interactional contexts in which knowledge is co-constructed and jointly used. This perspective is also supported by a current strand of CSCL research which aims to understand the *interactional mechanisms* that underlie collaborative learning contexts and the ways that they could explain particular collaborative outcomes—instead of trying to isolate the many factors that could, independently or through complex interactions, shape the dynamics and outcomes of collaboration (Dillenbourg, Baker, Blaye, & O'Malley, 1995). A number of these interactional mechanisms have been studied recently such as the *management of proposals* (Baron, 2003; Stahl, 2006b), *argumentation patterns*, *peer explanations*, *co-construction*, and others (e.g., Dansereau, 1988; Webb, 1992). We see our proposed research as expanding this line of inquiry by illuminating the interactional aspects of how progressive collective knowledge building evolves and, more specifically, how the bridging of *interactional episodes*, *collectivities*, and *perspectives* contributes to the sustainability of knowledge building.

Research Design and Methods

We propose to use the iterative framework of *design-based research* combined with *interaction/chat analysis* as our approach to data analysis. In particular, we intend to carry out a series of three design studies structured in a way to iteratively refine our understanding of *bridging* in the context of the VMT online community. We anticipate that these iterative cycles will aid us in refining our observations regarding how designed environments support bridging activity by allowing us to modify elements of the collaboration environment that are identified as related to bridging activity in order to test such observations. Each cycle is comprised of a design study in which a particular aspect of the theory in development will be explored in close relation to a design instance of the interaction environment being studied. For example, the first design study will engage participating teams in a sustained problem-solving task with no explicit supports for bridging being provided in the collaboration environment used by the virtual teams. Through this design study we intend to produce an initial characterization of the interactional methods and resources used by the teams to establish continuity of their knowledge-building task. Subsequent design studies will expand these initial observations; pursue new dimensions of the role of bridging in collaborative knowledge building, and continue to investigate the role of design artifacts in bridging. These studies are schematically summarized in Figure 1.

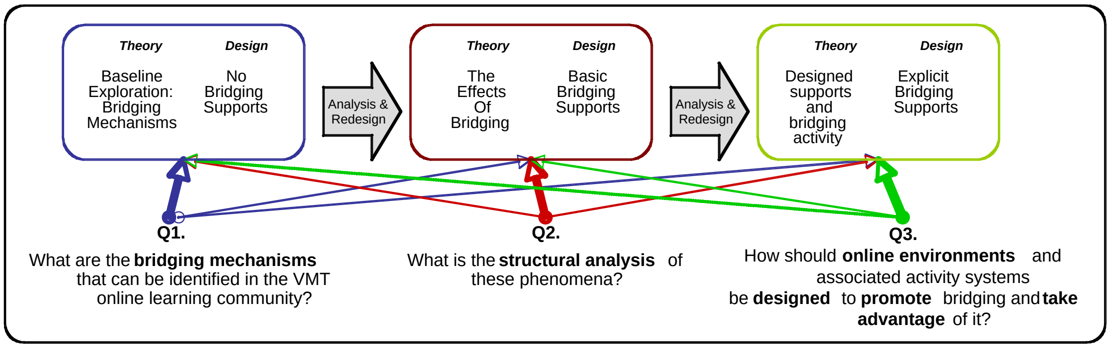

Figure 1. Design studies and research questions. The arrows indicate which design studies provide major and secondary data for each of the research questions.

In each study *five teams* or 3 to 5 secondary students will engage online as a virtual team working on an open-ended mathematical task for *at least four sessions*. Facilitators will provide feedback to each team asynchronously in between sessions, with observations about their collective work as well as the work of all other participating teams. The online environment will include a chat, a shared whiteboard tool and a wiki space. All interactions among the students during the sessions take place online and complete records of these interactions (chat posting, actions on the whiteboard, social awareness messages, etc.) are readily available for analysis. Special re-play software allows us to view and re-view at different speeds any part of the sessions, including all the information that was shared as it was displayed to the student participants. We will analyze data from each design study primarily using *interaction/chat analysis*. Our approach to interaction/chat analysis is informed by the tenets of *ethonomethodology* (Garfinkel, 1967; Patton, 1990), an inductive and naturalistic approach to qualitative social analysis which attempts to describe the *methods* that members of a culture use to accomplish what they do, such as carrying on conversations, using information systems, or doing mathematics. In our case, we inquire about how interactions in the online environment demonstrate the methods used to establish and sustain the teams' collective mathematical knowledge building. To do so, we will investigate patterns of interaction related to three *trajectories of engagement*: The *situated interaction* of the individual team members in a collaborative session, the emergent properties that come into view at the level of a *team's trajectory* (across episodes), and the ways that the teams refer to and use resources across teams and episodes to build *a community trajectory* of collaborative knowledge building.

Significance

The ultimate goal of the research plan presented in the preceding sections is that of increasing our understanding of how virtual learning teams and online communities establish and sustain continuity of their knowledge-building work. Because continuity in itself is important to the success of many collectivities involved with knowledge work and in particular those related to distributed virtual teams and online communities, the knowledge developed through this research will significantly contribute to emergent theories and designs for collaborative knowledge building in fields such as social computing, computer-supported collaborative learning, and information science and technology in general. By understanding this aspects of collaborative knowledge building, researchers in these fields will be better able to understand how members of online collectivities recognize, constitute, and use the boundaries emerging from their interactions (e.g., those related to multiple online sessions, sub-collectivities, and knowledge-perspectives). In addition, designers of online environments will be in a better position to support bridging activities through particular scafolds and to produce environments that take into account this very consequential phenomenon.

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Network Models of Online Communities of Creators

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Abstract: As online tools and social web sites become more popular, people are sharing more of their creations online. This thesis uses social network analysis to understand how community members share creations and learn from one another. It looks at the communities' network structure, how ideas diffuse through them, which ideas are adopted and incorporated into members' work, and how members describe the ways their work relates to others'.

Introduction

Online Communities of Creators (OCOCs) is a term I use to describe the subset of online communities in which the core activity is sharing personal creations. As online tools and social web sites become more popular, Online Communities of Creators are flourishing. In an OCOC a network of people is brought together by the projects they share. These communities provide new ways for people to learn together and for researchers to study how this learning occurs.

At the core of OCOCs are the objects people share and create. These creations are expressions of the creators' selves. When members post projects, they reveal bits of themselves. Through their work they create a public self for others to reflect upon. Thus, they are conscious of what they share, the attention it might garner, and how they hope others will react. Participants develop abilities that the communities value, be it programming, storytelling, image-making, or scientific questioning. Through these relationships and supported by their creations, they build online relationships with other members.

Some relationships within OCOCs can be quite strong, but many are weak. For instance, some people view each other's projects, but don't communicate personally. Strong ties provide less diversity of information than the weak ties someone might have with coworkers and acquaintances (Granovetter 1983). Chances are the people a person is most closely tied with may know each other and may be tapped into similar networks. More distant relations, or weak ties, can provide more connections to different communities with different values and knowledge. These weak ties provide a variety of important supports for individuals. In the context of OCOCs, having many weak ties likely means that an individual has greater access to new project ideas and to getting their ideas out to others. By describing who knows whom in a network of creators, one can tell who is influential, who is in a good position to have diverse social resources, and who is well positioned to receive new ideas.

Background

A small but growing group of CSCL researchers apply social network analysis (SNA) to learning environments. Social network analysis considers the structure of people in groups using statistical methods. The general shape of the network can be described numerically or graphically, specifying who is connected to whom, how strong the connections are, who contacts others via intermediaries and how ideas move through a network. The basic data needed to perform these types of analyses are represented as nodes (individuals) and edges or arcs (connections between the individuals.) An edge might simply represent whether a person knows another, how well they know each other, or whether an idea has moved from one person to another.

SNA allows researchers to understand not only social connections but also how ideas move through a network. The process by which groups adopt ideas is called diffusion of innovation. Diffusion of innovation is defined as the "the process by which an innovation is communicated through certain channels over time among members of a social system." (Beal & Bohlen 1955). When people choose to adopt new ideas depends on personal influences including centrality in a network and the age of the individual (Valente 1996).

Social network analysis not only provides several theories about how information moves through a network, but also provides methodologies that can be applied to how people work together. By tracking who contacts whom, who creates what, and where ideas are sent, researchers interested in learning can develop new understandings of how learners collaborate and learn from one another. Studying the network structure may provide insight into learning networks including important issues such as how much learners rely on each other versus teachers or mentors and the role of older children in younger children's experiences. Analysis of the flow of innovation can help researchers to understand how ideas catch on in a communities of learners, how the structure of the network influences who adopts when, what are the factors that influence widespread adoption and perhaps the structure of how people learn from one another.

A few CSCL researchers working with social networks focus on students in school, either face-to-face interactions in more traditional classrooms or in ones supported by online communication. Palonen, Hakkarainen and colleagues consider interactions among school students using CSILE (2000). McFarland studies formal and informal structures in classrooms and student defiance (2005a, 2005b). Reffay & Chanier model collaboration in distance learning groups (2003). Aviv et al found that in asynchronous learning networks that were structured had more student bridging and triggering discussion than unstructured ones (2003).

The Work

This thesis addresses four aspects of OCOCs First it describes the structure of the network, how people are connected with one another and what groups form within the networks. Second it describes how ideas diffuse through the networks, the characteristics of the ideas, the pathways the ideas flow through, and the characteristics of people who receive ideas. Then it considers which of these ideas are adopted by others and incorporated into their own work and learning. Finally it describes how members express how their work relates to others and what it means to them within the broader communities.

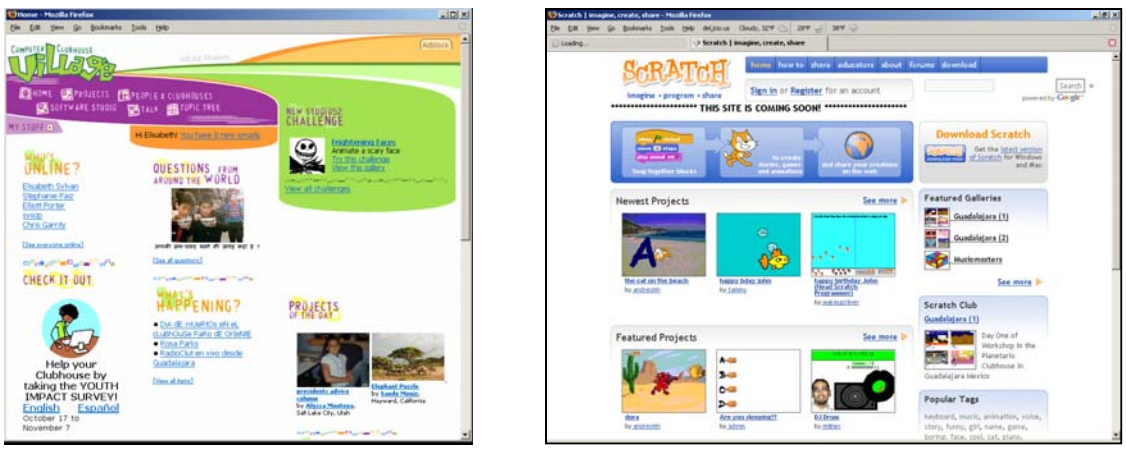

Figure 1. The Computer Clubhouse Village web site and the Scratch Web Site

The two communities studied are *the Village*, which is the online presence of the Intel Computer Clubhouse Network and *the Scratch web site*, which supports the Scratch software project. The Intel Computer Clubhouse Network is a network of 107 after-school computer learning centers for young people in under-served communities around the world (Computer Clubhouse web site n.d). The Clubhouse's Village is a web site used to share projects, discuss issues important to the members, and learn about each other through people's profiles and projects. Scratch is a visual programming environment developed by the MIT Media Lab that lets users create their own animations, games, and interactive art. The Scratchr web site is a community forum for people working with Scratch to share their projects and try out others' creations.

The social network analysis (SNA) of these two sites focuses on two important ideas in network theory: network structure and the diffusion of innovation. I use a variety of measures of connection such as email, buddy lists, and organizational membership and address both the whole network and particular clichés and partitions.

For the first area, network theory, I describe the relationships in the network using measures of centrality, cohesion, and social distance and identify different roles people have, depending on how the communicate and share content. By simply understanding the shape of the network, I identify the potential pathways by which sharing can occur, the roles that different members undertake, and any critical pathways for dissemination of ideas. I also address how people describe their own work and relate it to others using the communities' tagging and discussion features.

For the second area, diffusion of innovation, I engage in two areas of study. First I introduce new technological features to the communities, observe how the innovations spread over time, and study the features of the adopters and the patterns of adoption. Second, I map existing concepts of how ideas are diffused to behaviors in the communities (Table 1.) Rogers distinguishes diffusion of innovation from individuals' personal adoption. An individual's personal adoption goes through five stages: awareness, interest, evaluation, trial, and adoption. I propose that these stages are revealed by specific behaviors involving sharing in OCOC. Within OCOCs each of these stages can be seen as a deepening understanding of other community members' work. The first three stages-- awareness, interest and evaluation-- demonstrate attention to the other members' work. The last two stages, trial and adoption, represent members learning from each other by deeply exploring each other's work.

Table 1: Rogers Stages of Adoption and Related OCOC Behaviors.

Rogers' Stage	Definition of Stage	Behavior Characterizing Stage
Awareness	Member is exposed to idea.	Surfing projects.
Interest	Member is interested and seeks more information.	Revisiting, linking, forwarding.
Evaluation	Member evaluates whether to use idea.	Commenting upon others' work.
Trial	Member fully employs the idea.	Trying out ideas from the project.
Adoption	Member fully employs the idea.	Using others' concepts in work.

Through an understanding of how members of OCOCs learn and share in person and online and how they adopt each other's ideas in a range of ways, I hope to develop a theory of how OCOCs function including the four critical features: the network of members, the communication and exchange of ideas, the projects, and time. This understanding will include what features of a network support different exchanges and how those exchanges foster the creative design of individuals in the network. I will describe students' adaptation of one another's ideas by extracting specific social network and communication patterns of the major influencers. I hope to identify what predicts which members are influential and which ideas catch on.

Using network analysis to understand how Online Communities of Creators interact, share ideas and help each other's learning processes will likely reveal patterns that were previously not well understood. I hope this thesis will be profoundly informative about how learning occurs in groups, how people share and adopt ideas, and how they come to understand the way their work fits within their community.

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Toward Authentic Scientific Practice: Comparing the Use of GIS in the Classroom and Laboratory

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Abstract: A comparative case study juxtaposes activity in a scientific laboratory and a middle school classroom, in which both scientists and students use GIS software. Analyses will uncover how the participants, culture, and tools in each setting determine how the GIS is used and, in turn, how using GIS shapes participants' inquiry practices. There is much to learn about developing scientific thinking through this expert-novice comparison, with implications for the design and implementation of classroom technologies.

The Problem

In the 1910 issue of the journal *Science*, John Dewey remarked that "Science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind" (p. 122). An article in the same journal *Science* announced in its September 2006 issue that Pluto is not a planet after all (Schilling, 2006). Millions of Americans responded to the news with surprise and remonstration, as reflected in the dozens of talk shows and news articles that whined in the weeks thereafter, "How dare scientists change science on us like that!"

This widely held sentiment attests to a widely held view of science as an immutable set of facts and formulas, not as an activity of exploration and discovery despite efforts in the past several decades to bring scientific "methods of thinking"—or inquiry science—into the K-12 science curricula. The problem is inadequate time to teach both scientific content and inquiry in one class period, especially when content is delivered via didactic forms of instruction, separate of the structured lab experiments aimed at developing students' inquiry skills. The latter is more often sacrificed when class time is short. Fortunately, the recent proliferation of scientific investigation technologies adapted for K-12 classroom use—e.g., spreadsheets, visualizations, sensors, probes—offers new opportunities for students to collect, manage, and analyze real data in the context of the current lesson (Gordin & Pea, 1995; Krajcik et al, 1998) and simultaneously learn content and method. These tools help science learning better resemble science practice, heightening the much-desired element of *authenticity* in science classrooms (Brown, Collins, & Duguid, 1989; Edelson, 1997; Gordin & Pea, 1995). But do scientific investigation technologies actually promote authentic scientific practice (1)? Students may have access to scientists' tools, but are they using them in ways that scientists do? This study will examine in naturalistic settings whether and how these technologies foster "scientific habits of mind" (Dewey, 1938) and inquiry skills in students.

Conceptual Framework

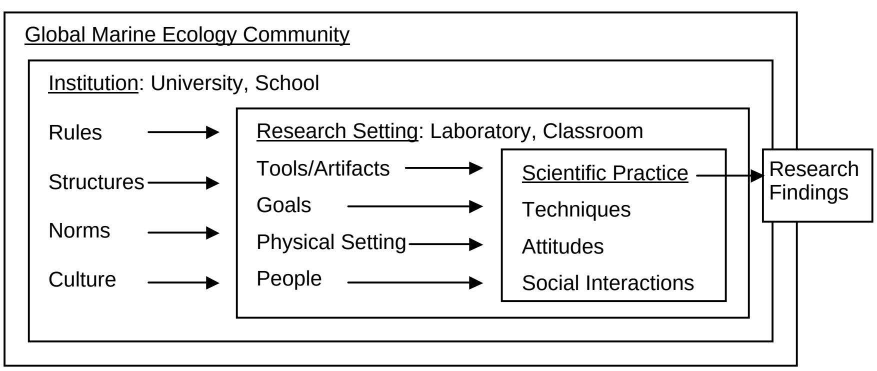

Figure 1. Influences of scientific practice

Figure 1 depicts the various factors that shape the inquiry practices of a scientific research team, which may comprise experts or novices. This framework allows us to look beyond individual actions and consider contextual factors to better understand how people learn and operate within a particular setting. Even if students have access to the same tools as scientists in a laboratory, the people, goals, and physical setup specific to a classroom also influence the inquiry practices that play out there (Engeström, 1999). Institutions affect inquiry practices, too, by imposing organizational constraints on the communities that fall within them. Because schools are not explicitly set up to support scientific research the way that professional laboratories are, there are bound to be occasions when school norms and structures clash with scientific practices.

Given the individual and contextual differences between the expert and novice systems, how do scientific investigation tools mediate the methods, social interactions, and attitudes of scientists? How do the goals, artifacts, culture, and institutional influences endemic to a setting mediate tool use? Do scientific investigation tools support inquiry practices in the classroom that are authentic?

Study Design

To begin to explore these questions, I am comparing two parallel activity systems (Engeström, 1999): an eighth grade oceanography classroom and a marine ecology laboratory, in which both students and scientists make use of geographical information systems (GIS), a certain type of analysis technology. I have chosen GIS as the study's focal technology for two reasons. First, GIS appeals to both scientists and educators because it transforms text data into map-based representations, facilitating analyses of spatial phenomena. Layering different data sets atop a base map can reveal spatial relationships that are otherwise imperceptible, such as the proximity of deep earthquakes to subduction zones. And because a growing variety of professions are using GIS, the National Research Council (2006) has called for a public commitment to incorporate GIS across the K-12 curriculum. Second, though GIS has been in schools for more than a decade now, few studies have investigated its role in supporting scientific practice. Most research on GIS in the K-12 classroom to date has focused on implementation issues, revealing the difficulty of integrating the technology into the culture and curriculum of schools (e.g., Audet & Paris, 1997; Kerski, 2001). Fortunately, recent improvements in the accessibility and reliability of computers in schools, and a proliferation of GIS software and curricula designed especially for learners may obviate earlier implementation concerns. Now is the time to focus on the potential of GIS in the K-12 science classroom.

Though my research is an expert-novice comparison, it differs from traditional studies of expertise. Rather than comparing how participants perform on routine tasks, I will examine how they deal with novel problems inevitably encountered in the course of their scientific research. I am interested in the development of "adaptive expertise," which is ever more valued in today's changing world, and characterized by ingenuity and the propensity to seek out and even generate learning resources (Hatano & Inagaki, 1986). And just as I regard my learners to be legitimate scientists—on the periphery of the scientific community, of course (Lave & Wenger, 1991)—I view my scientists as learners who must constantly acquire new knowledge to advance their research. Watching both groups tackle their learning needs—with or without GIS—may further our understandings of how ingenuity is best fostered.

Case Selection and Data Collection

To minimize the risk of technical or logistical GIS issues arising during the period of study, I selected a host teacher who has been teaching a GIS-based curriculum for five years and science for 20. This teacher was highly recommended by her peers in the national GIS-in-education community, including the producers of *My World*, the GIS software she uses in her teaching (2). Her eighth grade oceanography students spent 11 weeks conducting their own investigations of the subtidal ecologies of Catalina Island. This included a weeklong trip to Catalina to collect data, which they analyzed in the GIS afterward. Since few mixed-gender groups emerged out of the team formation process, I selected two case teams—a pair of boys and a pair of girls in separate periods—in anticipation of possible gender differences.

I identified potential scientists for my laboratory case based on two criteria: (1) their research in some way parallels the eighth graders' Catalina project, and (2) they use GIS in their work. I found a marine ecologist whose dissertation work on the subtidal ecologies of the central California coast fit the bill, and have enlisted him and his research assistant as my laboratory case. As it turns out, their research is so similar to that of the students, that they use identical data collection protocols and will share their findings within the same community of researchers.

Analysis

The purpose of the comparative design is twofold: First, to identify similarities and differences in the ways students and scientists use GIS to support their scientific practices. Second, to discover the particularities—namely the institutional and social arrangements, and tools and spaces—that work to promote or prohibit these practices. I will make both within- and between-setting comparisons to meet these objectives. *Within* each setting, I will catalog how participants use GIS in their work using Edelson's (1997) framework for categorizing scientific practices into tools, techniques, attitudes, and social interactions. *Between* settings, I will contrast how GIS mediates scientific practice on two levels borrowing Stevens' (1999) approach to examining mathematical activity across professional and school settings: Comparisons at the *interactional level* will provide an up-close look at how participants interact with each other and the artifacts in their environments. Comparisons at the *organizational level* will consider institutional forces that may account for disparities in scientific practice across the two settings. Activity Theory will help structure these comparisons, and illuminate significant points of tension (Engeström, 1999)—such as where laboratory practices clash with school norms—to use as focal analytic events.

In addition, I have drawn up a list of codes based on my theoretical framework, to which I am adding new themes as they emerge from collected data. I am applying this coding scheme to field notes, interview transcripts, and relevant artifacts to quantify and compare coding events across settings using qualitative data analysis software.

Implications

My comparison of two seemingly parallel systems is a starting point for exploring how forces outside of our immediate sight (e.g., institutional norms and structures) might account for differences in the way things play out in the two settings. My hope is that it will inform subsequent naturalistic studies of expertise aimed at discovering how we might adjust social arrangements, the school schedule, assessments, curriculum, and other materials to more closely align the practices of students to those of scientists. And by documenting my two case scientists' practices and the particular circumstances that have helped cultivate their adaptability and ingenuity, I hope to contribute to the larger effort of understanding the development of adaptive expertise, and bringing exploration and discovery into the K-12 science classroom.

End Notes

(1) I define "authentic" as Edelson & Reiser do, as "developmentally appropriate versions of the authentic practices of experts" (2006, p. 352).

(2) *My World GIS* was developed at Northwestern University as part of a research program on the adaptation of scientific visualization and data analysis tools to support inquiry-based learning.

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The Effects of Awareness of Group Members' Rationale on Collaborative Learning Activities

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Abstract: I designed a collaborative learning activity that requires the students to document their task-related rationales while working together, and I developed a collaborative workspace prototype that supports the distributed collaboration of the activity and provides shared document-based rationale spaces. In this study, I examine the effects of awareness of group members' rationale on the collaborative learning activity through a case study of the project management course in Spring 2007. In the class, students carry out the learning activity using the workspace prototype.

Problem Statement and Research Question

I design course activities that require students to document the rationale of the course content related decisions to promote reflective thinking in students (Schön, 1983). Requiring students to document meaningful rationale statements encourages students to reflect on their reasoning and may discover the flaws of their reasoning.

Research on collaborative learning has shown that working together for a common task outperforms individuals working alone by producing higher achievement and greater productivity (Johnson and Johnson, 1994). In a collaborative learning activity, if the students are aware of the rationales of other group members' task-related decisions available to his/her group members, how does this awareness affect the group activity? This is the research question that this study addresses. To explore the answer to this question, I first designed a collaborative learning activity that requires students to document the rationale on task-related decisions and developed a collaborative workspace prototype that supports distributed collaboration and provides shared document-based rationale spaces; and now I am investigating the effects of awareness of individual rationale on the group activity through a case study of the project management course in Spring 2007.

The Designed Collaborative Learning Activity

In the project management course of Spring 2007, the group project for the students is to research solutions for the success of distributed teamwork with respect to five project phases for a consulting company: initiation, planning, execution, planning, and closure. More specifically, there are five project phase activities in the group project. In each project phase activity, students group needs to identify the top challenges associated with each project management phase; select two to three technology tools and compare and contrast them; and identify several best practice recommendations for each project management phase. Each group will submit a mini-report at the end of each project phase activity. Within this project context, I designed a collaborative learning activity – *challenges assessment activity* – that starts at the beginning of each project phase activity and ends after two days.

Designing educational activities should follow criteria required in education domain. Constructivists suggest that there are five principles in designing an educational activity (Newman, Griffin, & Cole, 1989):

Constructive: The activity integrates students' existing knowledge schemes with new information to support acquisition of new knowledge

Active: Each student is expected to participate in the activity actively in generating new knowledge and learning from peers.

Significant: Learning should be meaningful to each individual student.

Reflexive: The learning group in the activity acts as a mirror reflecting each student's learning process.

Collaborative: The activity supports students to learn with their group members. Student group has the same pedagogical goal, and each member is a potential source of information

In addition, there are criteria for an activity for which collaborative learning model is most appropriate (Johnson and Johnson, 1994): 1). The task is complex enough or conceptual; 2). Problem solving environment is desired; 3). Divergent thinking is desired; 3). Mastery. 4). High-level, critical thinking is required; 5) Quality of performance is necessary. Using these criteria, I designed the challenges assessment activity as follows:

In the activity, the students need to answer two questions as a group: 1). What are the types of challenges for the success of distributed teamwork at the particular project phase? 2). What are the top three and bottom three challenges for the success of distributed teamwork? To answer the first question, students need to propose at least thirty challenges as a group, and then categorize the challenges into at least three types. For each challenge that a student proposes, he/she needs to give the reason of why he/she thinks it to be a challenge, i.e., the rationale of his/her decision on whether it is a challenge for the success of distributed teamwork or not. To answer the second question, each student should select top three and bottom three challenges from the challenges they have proposed in answering the first question, and give the reason of why he/she selects those to be top three and bottom three challenges, i.e., the rationale of his/her decision on choosing the top three and bottom three challenges. The group will then select top three and bottom challenges as a whole, and gives a group rationale of the choices.

During the challenges assessment activity, everyone's rationale is shared within the group once it is written. Students are encouraged to comment on each other's rationale. The students are required to only use the collaborative tool for collaboration and are not allowed to meet face-to-face. The rationale behind this requirement is that the students really need to have some level of distributed teamwork experience in order to be able to suggest solutions for the success of distributed teamwork.

According to Tuckman (1965), only after the group members establish boundaries, feel comfortable about each other, and their behaviors become normalized, can they really begin to perform and become a team that achieves its objective. The first challenges assessment launched on Feb. 13th, about three weeks after the groups are formed, taking into account Tuckman's point.

A Collaborative Workspace that Supporting Rationale Sharing

There are several areas in the workspace interface: user panel (A), file organization panel (B), desktop area for displaying the document and its rationale (C and D), and group chat panel (E). For each group document (C), there is a rationale document (D) associated with it. When a user opens a group document, its rationale document is automatically opened and displayed in parallel to the group document. Similar to an affinity diagram process, the students post challenge notes to a shared whiteboard in the workspace and move the notes around to form the categories of the challenges. The product of this is a challenges map that shows all the challenge notes and the formed categories. Students in general use color scheme to show whom each note belongs to on the whiteboard. Students write down their choices of top three and bottom three challenges in a shared spreadsheet. Figure 1 is a screen shot of the workspace used by a students group during the second project phase activity's challenges assessment.

Theoretical Framework

Carroll et al. posit shared activity as a basis for awareness and coordination (Carroll et al., 2003, 2006). The term "activity" refers to the substantial and coherent collective endeavors with meaningful objectives, built upon the theoretical and empirical foundations of Activity Theory (Bertelsen and Bødker, 2003). Activity awareness refers to the awareness of the group activity that includes various kinds of information related to the activity such as interaction patterns, communication protocols, status of the individual tasks, plans of individuals, goals and sub-goals of the activity, norms, social dynamics, etc. Carroll et al. maintain, "Many aspects of activity awareness are intentional in the sense that the information or event that collaborators need to become aware of is the state of someone else's mind" (Carroll et al., 2003). A member's rationale about his/her shared group work is part of the state, thus the awareness of the group members' rationale is part of the activity awareness.

Carroll et al. proposed an activity awareness framework for studying the effects of activity awareness on the group activity (Carroll et al., 2006). The framework presents four constructs of activity awareness: *common ground, community of practice, social capital,* and *human development* (Carroll et al., 2006). In this study, I use the activity awareness framework to guide me in exploring the effects of awareness of individual rationale on the collaborative learning activity. My data source include *direct observation* and *note taking, questionnaire, semi-structured interview, students' reflective notes,* and *students' coursework.*

Research Contribution

There has been little study of how awareness of other member's rationales in a group project affects group activity. This work is framed as an exploratory study aiming at better understanding the effects of individual rationale on the overall group activity. First, this research will be a contribution to Computer-Supported Cooperative Work. Today, it is routine to consider how to address requirements for supporting situation awareness, social awareness, and workspace awareness in developing collaborative systems. Understanding the effects of awareness of individual rationale inspires the design of awareness techniques for group activity. Second, this research will be a contribution to Computer-Supported Collaborative Learning. There will be lessons learned from the students' experience of working with peers through the collaborative tool. These lessons inspire the design of learning technologies to support collaborative learning activities in higher education. Third, this research makes a methodological contribution to the measurement of activity awareness in virtual collaboration. Last, this research makes a contribution to the instructional system design. The effectiveness of the designed collaborative learning activity on supporting reflective thinking will be examined. The finding is expected to suggest design principles of instructional activities on promoting reflective thinking in students.

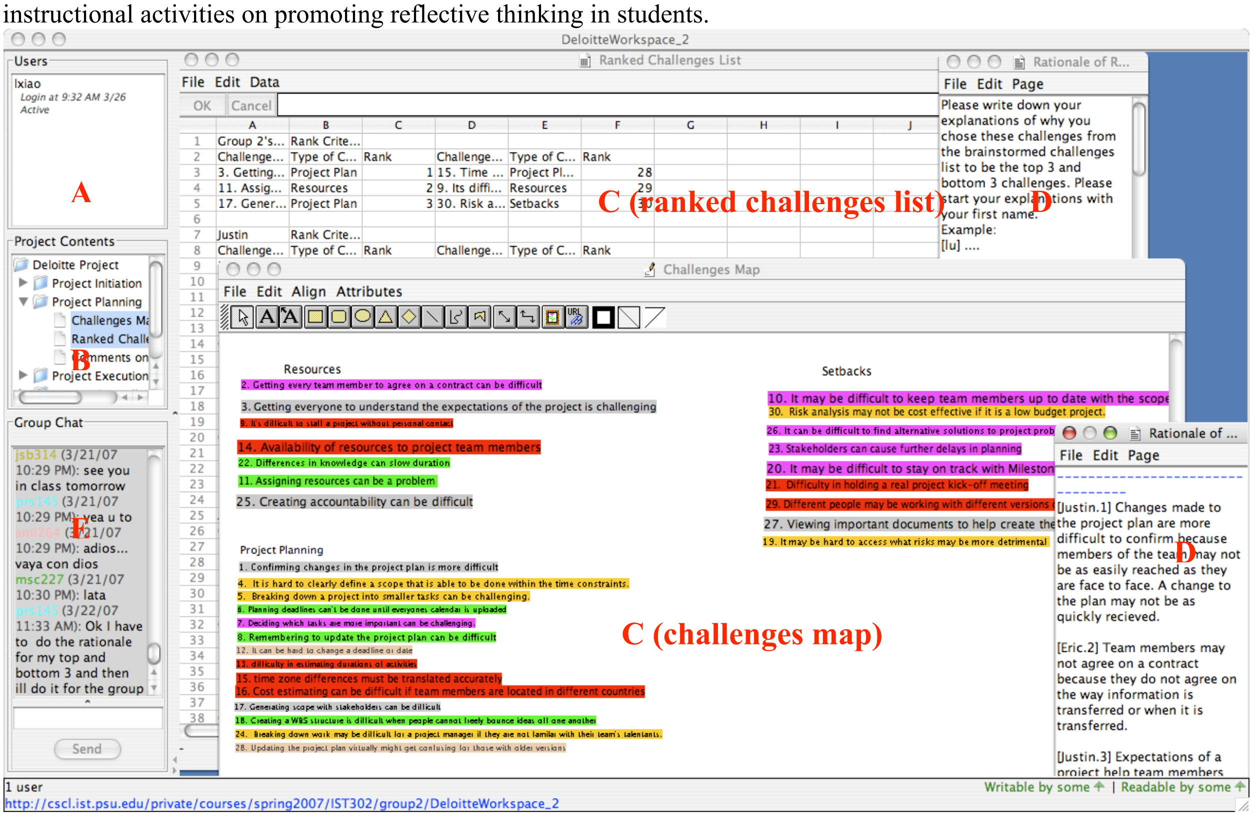

Figure 1. A Screenshot of the workspace used by a students group during a challenges assessment activity (Both the shared whiteboard and the shared data spreadsheet are open, and so do their rationale documents)

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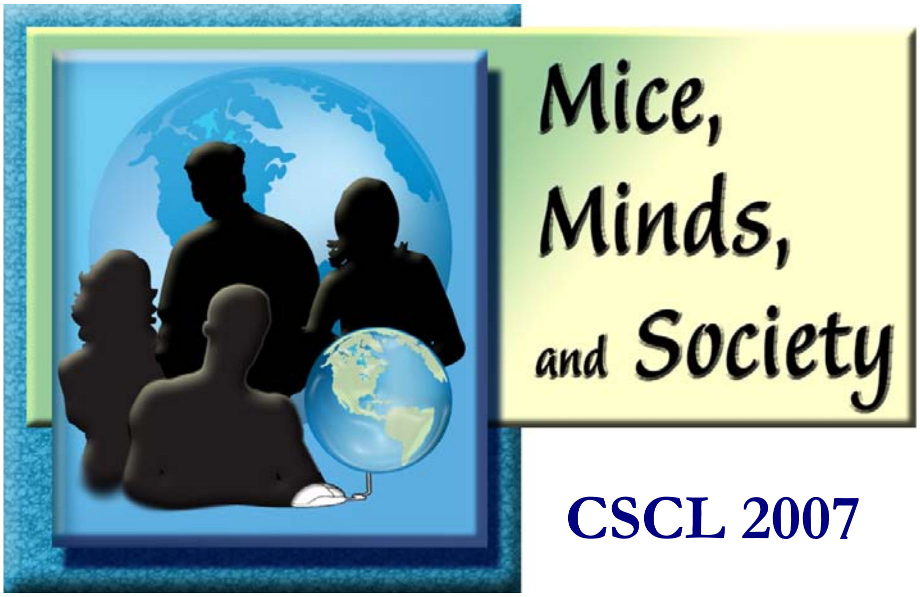

CSCL 2007

The Computer Supported Collaborative Learning (CSCL) Conference 2007, Volume 8

July 16 - July 21
Rutgers, The State University of New Jersey
New Brunswick, NJ, USA

ISSN 1819-0146