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Mice, Minds, and Society

CSCL 2007

The Computer Supported Collaborative Learning (CSCL) Conference 2007, Volume 8, Part 1

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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Rutgers University

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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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The conference organizers and program chairs sincerely thank the following individuals who served on the program committee and who reviewed proposals for the CSCL 2007 conference:

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Keynote

Designing Socio-Technical Environments in Support of Meta-Design and Social Creativity

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Abstract: This paper provides elements of a *transformational conceptual framework* for CSCL by focusing on how learning takes place when the answer is not known (this being the case for complex design problems in numerous domains encountered in lifelong learning activities).
The paper postulates, explores, and discusses visions, theories, systems, practices, and methods for CSCL with a focus on *reflective communities* (bringing stakeholders together from many different backgrounds, requiring cultural and epistemological pluralism to make all voices heard*), meta-design* (allowing owners of problems to act as designers and active contributors, and not only as consumers*), and social creativity* (bringing different and often controversial points of view together to create a shared understanding among stakeholders that can lead to new insights, new ideas, and new artifacts).
Innovative *socio-technical environments* are needed to make progress in achieving these objectives. Examples and characteristics of such environments will be briefly presented and discussed. Some implications and challenges for future research in CSCL are derived and articulated.

Keywords
reflective communities, design, meta-design, social production, social creativity, socio-technical environments, symmetry of ignorance, gift-wrapping

Introduction

The goal of the CSCL community and in particular its 2007 conference ("*Of Mice, Minds, and Society*") is to sharpen the community's perspectives on how visions, theories, systems, practices, and methods of CSCL are interwoven and how they interactively contribute to an understanding of the nature of learning in technology-supported environments.

I will argue in this paper that CSCL is not thinking *radically* enough (1) by accepting too many established approaches and organizations (e.g.: a theory of human learning based solely on school learning is too limited), (2) by not embracing new learning opportunities (e.g.: exploiting the unique opportunities of social production in which all learners can act as active contributors in personally meaningful problems), and (3) by not providing broader conceptual frameworks for learning in the 21st century. I believe that the CSCL community can and should act as the engine of innovation and radical transformation and contribute to changing the public understanding of learning, collaboration, expertise, attention, control, freedom, and creativity in the digital age.

My contribution is shaped by having participated in the CSCL community from its beginning, by identifying interesting themes in related disciplines (such as computer supported cooperative work, human computer interaction, design, and the learning sciences), and by our research work in the Center for LifeLong Learning & Design (L3D) over the last decade.

Why Now: Opportunities and Challenges?

Stephen Jay Gould argues for the theory of *"punctuated equilibrium"* in biology (long periods of slow change are interspersed with periods of rapid change) and social systems may follow a similar pattern (Collins & Halverson, 2006). People from various scientific disciplines (Benkler, 2006; Bereiter, 2002; Florida, 2002; Tapscott & Williams, 2006) have argued that we are in the midst of a technological, economic, and organizational perturbation, innovation, and transformation that allows us to rethink, renegotiate, and redefine learning, working, and collaboration. One of the fundamental changes taking place is the democratization of knowledge creation, innovation, and creativity (O'Reilly, 2006; Raymond & Young, 2001; von Hippel, 2005). The industrial information society specialized in producing finished goods (like movies, music, software systems, and learning environments) to be specified fully at design time and consumed passively at use time. The emerging networked information society is focusing on the demands of active contributors for evolvable environments (including platforms, seeds, and tools) that are "underdesigned." *Underdesign (Brand, 1995; Fischer & Ostwald, 2005)* in this context does not mean less work and fewer demands for the design team, but it is fundamentally different from creating complete systems. The primary challenge of underdesign lies not in developing specific solutions, but in designing environments that allow the *"owners of problems*" to create solutions themselves at use time. This can be done by providing a seed against which situated cases that arise later can be interpreted. Underdesign is a defining activity for meta-design aimed at creating design spaces for others.

Themes developed in the past for CSCW and CSCL research have often focused on how standardized processes were embedded in workflow systems and curriculum-driven learning environments and how homogenous communities of practice could be supported. Future themes need to be focused on how to improvise, innovate, and learn when the answer is not known, and how to bring different communities of practice together in communities of interest to avoid group think and to exploit the opportunities provided by the *symmetry of ignorance* (Fischer & Ostwald, 2005), *conceptual collisions* (J. Bransford *et al.*, 2006), and *epistemological pluralism* (Turkle & Papert, 1991) by making all voices heard. This is especially important at a time where many high level objectives in education are focused on a climate for test taking, bookkeeping, and cutting expenses—the wrong strategies as economic competition heats up around the globe and societies are exploring news ways to make their individual members more creative, imaginative, and innovative (Friedman, 2005).

Lifelong Learning: A Focus for CSCL

Learning needs to be examined across the lifespan because previous notions of a divided lifetime (education followed by work) are no longer tenable (Gardner, 1991). Professional activity has become so knowledge-intensive and fluid in content that learning has become an integral and irremovable part of work activities. Learning is a new form of labor and working is often (and needs to be) a collaborative effort among colleagues and peers. In the emerging knowledge society, an educated person will be someone who is willing to consider learning as a lifelong process. More and more knowledge, especially advanced knowledge, is acquired well past the age of formal schooling, and in many situations through educational processes that do not center on the traditional school (Illich, 1971). In preparing learners to live and work in the knowledge age (Bereiter, 2002), one cannot predict or learn in educational settings what one may need to know during a lifetime of work. Coverage is impossible and obsolescence is guaranteed. CSCL should do a better job of empowering all students to be prepared for future learning and to learn on demand by exploiting the powers of collaboration and new media (Bereiter & Scardamalia, 2006; Fischer, 2000).

Lifelong learning in the world today is a necessity (*"The ultimate goal of education is to prepare students to become competent adults and lifelong learners"(J. D. Bransford et al., 2001)*) and people need to acquire the cognitive and social skills necessary for self-directed, lifelong learning (Drucker, 1994). Our credo for lifelong learning can be formulated as follows: "*If the world of working and living relies on collaboration, creativity, definition and framing of problems and if it requires dealing with uncertainty, change, and intelligence that is distributed across cultures, disciplines, and tools—then learning and education should foster competencies that prepare learners for having meaningful and productive lives in such a world."*

By *integrating working and learning*, people learn within the context of their work on real-world problems. Learning does not take place in a separate phase and in a separate place, but is integrated into the work process. People construct solutions to their own problems, and the socio-technical environment advises them when they are getting into trouble and provides directly relevant information. The direct usefulness of new knowledge for actual problem situations greatly improves the motivation to learn the new material because the time and effort invested in learning are immediately worthwhile for the task at hand—not merely for some putative long-term gain. The need to base innovations in learning on more than learning in schools is articulated by (Scribner & Sachs, 1990) as follows: *"A decade of interdisciplinary research on everyday cognition demonstrates that school-based learning, and learning in practical settings, have significant discontinuities. We can no longer assume that what we discover about learning in schools is sufficient for a theory of human learning."*

Lifelong learning is a continuous engagement in acquiring and applying knowledge and skills in the context of self-directed problems and should be grounded in descriptive and prescriptive goals such as (Hmelo-Silver, 2004):

- learning should take place in the context of authentic, complex problems (because learners will refuse to quietly listen to someone else's answers to someone else's questions);
- learning should be embedded in the pursuit of intrinsically rewarding activities;
- learning on demand needs to be supported because change is inevitable, coverage is impossible, and obsolescence is unavoidable;
- organizational and collaborative learning must be supported because the individual human mind is limited; and
- skills and processes that support learning as a lifetime habit must be developed.

Understanding and exploring *design* and the *framing and solving* of complex design problems (Simon, 1996) represent fundamental challenges for lifelong learning and these activities provide a rich setting in which to study and apply CSCL. Large and complex design projects cannot be accomplished by any single person, and they often cut across different established disciplines, requiring expertise in a wide range of areas (Arias *et al.*, 2001). Software design projects, for example, involve domain experts, designers, programmers, human-computer interaction specialists, marketing people, and user participants. Design projects are *unique*, and therefore each design project requires learning and produces new knowledge in the form of understanding as well as artifacts. Learners engaged in design must be willing to cope with the uncertain, the unproven, and the ambiguous. Complexity in design arises from the need to synthesize stakeholders' different perspectives of a problem, the management of large amounts of information relevant to a design task, and understanding the design decisions that have determined the long-term evolution of a designed artifact. Successful projects must overcome many barriers to communication and shared understanding. Media and technologies have fundamentally changed the nature of learning and communication in design.

In the effort to develop a coherent and unique intellectual identity for CSCL, there is a rich source of interesting concepts including:

- *distributed intelligence* (Salomon, 1993) — the idea that intelligence is not located in a single mind but is distributed among people and tools that work together and emerges in the process of problem solving;
- *models of community* (Fischer & Ostwald, 2005) — how shared knowledge and common ground is created to support mutual learning and collaborative problem-solving;
- *reflection* (Schön, 1983) — how cognitive skills can help individuals and communities intelligently monitor, assess, and adapt their work through processes such as "reflection-in-action" and "reflection-on-action";
- *boundary objects* (Bowker & Star, 2000) (Star, 1989) — how entities (such as products, standards, or ideas) can serve as communicative interfaces between members of different communities and how they help or hinder collaboration;
- *open, living systems* requiring meta-design approaches (Fischer & Giaccardi, 2006) — how to redistribute power, control, and responsibility by supporting the "creative milieu" in which learners are able to exercise their creativity; and
- *socio-technical design* (Mumford, 1987; Trist, 1981) — how can the evolutionary creation of effective learning and problem-solving environments be made possible with new media with a focus on the interaction between social and technical components.

From Reflective Practitioners to Reflective Communities

The objective of educating "Renaissance scholars" (such as Leonardo da Vinci, who was equally adept in the arts and the sciences (Shneiderman, 2002)) is not reasonable in today's world (National-Research-Council, 2003). We need to invent alternative social organizations that will support "*collective comprehensiveness through overlapping patterns of unique narrowness*" (Campbell, 2005) by integrating different interdisciplinary specialties which are partially overlapping with each other. Such architectures will provide a foundation that people can understand each other based on common ground but at the same time their expertise will be complementary because they will know different things. In doing so, we will move beyond the isolated image of the reflective practitioner towards the sustainability and development of *reflective communities*.

Reflective communities are social structures that enable groups of people to share knowledge and resources in support of collaborative design, working, and learning. Some characteristics of communities being reflective are: avoiding to be stuck in "group think", support for reflection-in-action and reflection-on-action, critiquing (Fischer *et al.*, 1998) establishing common ground and shared understanding, and maintaining group productivity with joint attention (Barron, 2000). Effective reflective communities must be aware of barriers and biases in computer-mediated collaboration and must exploit opportunities with the support of socio-technical environments (Bromme *et al.*, 2005).

Different communities grow around different types of design practice and each design community is unique. Two communities will be briefly discussed: *communities of practice* (CoPs) (Wenger, 1998) and *communities of interest* (CoIs) (Fischer & Ostwald, 2005).

CoPs consist of practitioners who work as a community in a certain domain. Learning within a CoP takes the form of *legitimate peripheral participation* (Wenger, 1998), an apprenticeship model in which newcomers enter the community from the periphery and move toward the center as they become more and more knowledgeable. Sustained engagement and collaboration lead to boundaries that are based on shared histories of learning which create discontinuities between participants and non-participants. Highly developed knowledge systems are biased toward efficient communication *within* the community at the expense of acting as barriers to communication with outsiders: boundaries that are empowering to the insider are often barriers to outsiders and newcomers to the group.

CoIs bring together stakeholders from different CoPs; they form by their collective concern with the resolution of a particular problem and they can be defined as "communities of communities". Examples of CoIs are: (1) teams interested in software development that includes software designers, users, marketing specialists, psychologists, and programmers, (2) groups of citizens and experts interested in urban planning, and (3) domain experts, media specialists, teachers, and learners exploring the design of new innovative learning environments. Collaborative design problems explored by CoIs represent ideal candidates to explore, understand, and support *learning when the answer is not known*. Because design problems are unique, the knowledge to understand, frame, and solve these problems does not already exist, but must be collaboratively constructed and evolved during the problem framing and solving process. The primary role of media in such settings is not to deliver pre-digested information to individuals, but to provide the opportunity and resources for social debate and discussion (Bruner, 1996) by allowing stakeholders to incrementally acquire ownership in problems and contribute actively to their solutions. The fundamental barrier and opportunity facing CoIs is that knowledge distribution is based on a *symmetry of ignorance (or knowledge)* (Fischer & Ostwald, 2005), in which each stakeholder possesses some, but not all, relevant knowledge, and the knowledge of one participant complements the ignorance of another (Engeström, 2001).

Meta-Design: A Methodology for CSCL

In an unpredictable world, improvisation, evolution, and innovation are more than a luxury: they are a necessity. The challenge of design is not a matter of getting rid of the emergent, but rather of including it and making it an opportunity for more creative and more adequate solutions to problems. Unfortunately, a large number of media are designed from a perspective of seeing and treating humans primarily as consumers (Fischer, 2002). Rather than providing access only to a small group of "high-tech scribes," media need to be designed to allow all participants to be and act *as designers* when they desire to do so, specifically in *personally meaningful and important activities.*

Meta-design (Fischer & Giaccardi, 2006) is focused on "design for designers": an emerging conceptual framework aimed at defining and creating social and technical infrastructures in which new forms of collaborative design can take place. It extends the traditional notion of system design beyond the original development of a system. It is grounded in the basic assumption that future uses and problems cannot be completely anticipated at design time when a system is developed. Users, at use time, will discover mismatches between their needs and the support that an existing system can provide for them. These mismatches will lead to breakdowns that serve as potential sources of new insights, new knowledge, and new understanding. In our research we are investigating fundamental aspects of meta-design such as:

- approaches for supporting domain-orientation by bringing tasks to the forefront and providing time on task, thereby supporting specific communities of practice;

- the use of techniques such as critiquing, simulations, and argumentation to increase the back-talk of the artifacts;
- frameworks and principles for the creation of open, evolvable systems to put owners of problems in charge, allowing users to invest the world with their own meaning;
- collaborative technologies to allow all participants to move from access to informed participation.

Meta-design is of specific importance for ill-defined, wicked design problems (Rittel, 1984) that cannot be delegated (e.g., from problem owners to computer professionals) because they are not understood well enough to be described in sufficient detail. Partial solutions need to "talk back" (Schön, 1983) to the owners of the problems who have the necessary knowledge to incrementally refine them.

Social Creativity: The Potential of CSCL

Meta-design advocates a shift in focus from finished products or complete solutions to conditions, contexts, and tools for users that allow them to be creative in further evolving artifacts and organizations (von Hippel, 2005). Meta-design supports *creativity* in which participants from all walks of life (not just skilled professionals) transcend the information given to incrementally acquire ownership in problems and to contribute actively to their solutions. Creative communities require *active contributors* (people acting as designers in personally meaningful activities), not just consumers (Fischer, 2002). Creativity needs the "synergy of many," and this kind of synergy is facilitated by meta-design. However, a tension exists between creativity and organization. A defining characteristic of social creativity is that it transcends individual creativity and thus requires some form of organization but elements of organization can and frequently do stifle creativity (Florida, 2002).

The claim by Csikszentmihályi (Csikszentmihalyi, 1996) that *"an idea or product that deserves the label 'creative' arises from the synergy of many sources and not only from the mind of a single person"*, does not exclude individual creativity. Creative individuals can make a difference in exemplary cases, such as movie directors, champions of sports teams, and leading scientists and politicians. Individual creativity comes from the unique perspective that the individual brings to bear in the current problem or situation. It is the result of the life experience, culture, education, and background knowledge that the individual has, as well as the personal meaningfulness that the individual finds in the current situation. Creative actions cannot be completely planned actions: they are situated actions exploring the resources available in reflective communities (such as: willingness to take risks and to persevere when things go wrong, understanding that problems will not have unique solutions, and coping with ambiguity). Creativity flourishes best in a unique kind of social environment: one that is *stable* enough to allow continuity of effort, yet *diverse and broad-minded* enough to nourish creativity in all its subversive forms.

Much human creativity arises from activities that take place in a social context in which interactions with other people and the shared artifacts are important contributors to the process. Social creativity comes alive in socio-technical environments in which communities collaborate and in which symmetry of ignorance, conceptual collisions, and epistemological pluralism are appreciated and exploited as sources of creativity.

Communities can be characterized by distances and diversity and by the resulting *division of labor* (Levy & Murnane, 2004), among individuals who have unique experiences, varying interests, and different perspectives about problems, and who use different knowledge systems in their work (characteristics which are associated with communities of interest). Distances and diversity should not be considered as constraints and barriers but as opportunities to generate new ideas, new insights, and new environments (National-Research-Council, 2003). The challenge is often not to reduce heterogeneity and specialization, but to support it, manage it, and integrate it by finding ways to build bridges between local knowledge sources and by exploiting conceptual collisions and breakdowns as sources for innovation. Social creativity can be distributed (Derry & Fischer, 2007): (1) *spatially* (across physical distance); (2) *temporally* (across time); (3) *conceptually* (across different communities); and (4) *technologically* (between persons and artifacts). Creativity can be enhanced by integrating diversity, making all voices heard, increasing the back-talk of the situation, and providing systems that are open and transparent, so that people can be aware of and access each other's work, relate it to their own work, transcend the information given, and contribute the results back to the community.

Externalizations (Bruner, 1996) (such as components, partial work products, design rationale, catalogs of existing solutions) are critically more important for social interactions because groups have "no head." Externalizations support creativity by: (1) producing a record of our mental efforts that is outside us rather than vaguely in memory; (2) causing us to move from vague mental conceptualizations of an idea to a more concrete representation of it, creating situational back-talk and making thoughts and intentions more accessible to reflection; (3) providing a means for others to interact with, react to, negotiate around, and build upon an idea (especially if they are represented as boundary objects); and (4) contributing to a common language of understanding.

Socio-Technical Design: Environments Supporting CSCL

There is *no media-independent* communication or interaction: tools, materials, and social arrangements always mediate activity. The processes of thinking, learning, working, and collaborating are all functions of our media (Bruner, 1996). Cognition is shared not only among minds, but among minds and the structured media within which minds interact (Salomon, 1993). Major advances in the development of the human race and societies have come not from increases in brain size, but rather from the steady accretion of new tools for intellectual work (the major development being the transition from an oral to a literate society). As we enter a world of *"pervasive computing, with always-on Internet access, reliable quality of service networks, and sufficient levels of technological fluency"* (Pea, 2004), we must address how socio-technical design and environments *will* shape 21st century learning and education.

Many current educational uses of technology are restricted to what can be thought of as *gift wrapping (Fischer, 2000)*: meaning, technology is used as an add-on to traditional practices rather than as a catalyst for fundamentally rethinking what education and learning should and could be. But shortcomings of traditional practices (such as passivity in lectures, fixed curricula, memorization, and decontextualized learning) are not overcome by introducing technology, whether that technology takes the form of intelligent tutoring, multimedia presentations, or distance learning.

Learners should not only learn *with* new media (changing the *how* by learning differently); they must also learn *about* new media (changing the *what* by learning different things); and new models of distributed intelligence need to be explored (Derry & Fischer, 2007). S*ocio-technical design* encourages learners to become active designers. The design of new socio-technical environments should be conceptualized in the dialectical tension between *tradition* (to avoid techno-centrism) and *transcendence* (to avoid gift-wrapping) (Ehn, 1989). Learners need to practice the cognitive, interactional, social, and technical skills necessary for self-directed, lifelong learning required for the 21st century. Media and technologies for learning must not only deliver predigested information to individuals, but provide support and resources for discussion, social debate, and collaborative design (Bruner, 1996).

The *Seeding, Evolutionary Growth, and Reseeding (SER) Process Model* (Fischer *et al.*, 2001) depicts the lifecycle of large evolving socio-technical environments as developed by reflective communities. It postulates that systems that evolve over a sustained time span must continually alternate between periods of unplanned evolutions and periods of deliberate (re)structuring and enhancement. The SER model encourages system designers to conceptualize their activity as meta-design, thereby aiming to support users as active contributors. We have explored the feasibility and usefulness of the SER model for reflective communities engaged in the development of urban planning environments, organizational memories, course information environments, and open source systems. The evolution of these systems share common elements, all of which relate to sustained knowledge use and construction in support of informed participation.

Examples

Developments in coping with complex design problems of the last few years have been based on effective, large-scale collaborative efforts. These developments are most prominent in

- *open-source software* (Raymond & Young, 2001) — an activity in which a community of software developers collaboratively construct systems to help solve problems of shared interest and for mutual benefit;
- *collaboratively constructed encyclopedias* (Benkler, 2006) — with Wikipedia being the most visible example: an example of a collaborative design activity producing content that harnesses the contribution of many minds;
- *massively multiplayer online games* (Tapscott & Williams, 2006) — such as Second Life, a virtual environment in which almost all content is contributed by the players; and
- *knowledge building* (Bereiter & Scardamalia, 2006) — with a focus on conceptual artifacts such as theories, designs and plans and supported by knowledge building environments.

The Internet and associated Web 2.0 technologies (O'Reilly, 2006) serves as a communication medium that expands and supports social creativity by decentralizing production and distribution with meta-design. The developments of peer production of information, knowledge, and culture (Benkler, 2006) represent a unique moment of opportunity and challenge, in which the CSCL community could and should be a leader, not just a follower. The concepts briefly described in this paper (reflective communities, meta-design, and social creativity) are well suited as a starting point to develop a conceptual framework for a deeper understanding of these developments.

In our research activities we have *self-applied* the emerging conceptual framework discussed in the paper to our own research, learning, and teaching activities. I will briefly describe two of these efforts.

The Envisionment and Discovery Collaboratory (EDC). As argued before: most significant real-world design problems are framed and solved by groups of individuals rather than by individuals in isolation. The EDC (Arias et al., 2001) is a long-term research platform exploring conceptual frameworks for new paradigms of learning (including collaborative learning, self-directed learning, and learning on demand) in the context of design problems where the answer is not known. It represents a socio-technical environment supporting reflective communities by incorporating a number of innovative technologies including: table-top computing environments, the integration of physical and computational components supporting new interaction techniques, and an open architecture supporting meta-design activities.

The vision of the EDC is to provide contextualized support for reflection-in-action (Schön, 1983) within collaborative design activities. It brings together participants from various backgrounds to collaborate in resolving design problems. The contexts explored in the EDC (e.g., urban planning, emergency management, and building design) are all examples of ill-defined, open-ended design problems. The knowledge to understand, frame, and solve these problems does not already exist (Engeström, 2001) but is constructed and evolves during the solution process.

The EDC shifts the focus of design activities away from the computer towards an increased understanding of the human, social, and cultural system that defines the context in which systems are used. It serves as an immersive social context in which a community of stakeholders can create, integrate, and disseminate information relevant to their lives and the problems they face. Providing multiple avenues for participation and boundary objects is important because participants in the EDC may not share a common background. They represent a community of interest, bringing together stakeholders from different domains who have different background knowledge and different things to contribute. The exchange of information is encouraged by providing stakeholders with tools to express their own opinions, requiring an open system that can accommodate and evolve based on new information. For example, city planners contribute formal information (such as the detailed planning data found in Geographic Information Systems), whereas citizens may use less formal techniques (such as sketching and using Google Earth for embedding the sketches in authentic environments) to describe a situation from their points of view.

Our research activities centered around the EDC are currently further evolved and extended within a project supported by the NSF-CISE "Science of Design" Program entitled *"A Meta-Design Framework for Participative Software Systems"* in which we explore (1) how *participative software systems* can achieve the best fit between the software system and its ever-changing context of use, problems, domains, users, and communities of users; (2) the *scientific foundation* for designing participative software systems as socio-technical environments that empower users, as owners of problems, to engage actively and collaboratively in the continual development of software systems; (3) a *meta-design framework* to guide software developers to design participative software systems; and (4) a demonstration that meta-designed systems can be supported by the *Seeding, Evolutionary Growth, and Reseeding (SER)* process model.

Courses-as-seeds (dePaula *et al.*, 2001) is an educational model that explores meta-design and social creativity in the context of fundamentally changing the nature of courses taught in universities. Its goal is to create a culture of informed participation (Fischer & Ostwald, 2005) that is situated in the context of university courses transcending the temporal boundaries of semester-based classes. Traditionally, the content of a course is defined by the resources provided by instructors (such as lectures, readings, and assignments). By involving students as active contributors, courses do not have to rely only on the intellectual capital provided by the instructors. Courses are conceptualized based on the SER model, in which the instructor provides the initial seed rather than a finished product (Rogoff *et al.*, 1998).

An essential aspect of courses-as-seeds is the transformation of traditional classroom roles. Students act as active contributors—active not only in the assignments that are given to them, but also active in the design of the courses themselves. Instructors' roles are likewise transformed from a "sage on the stage" to a "coach on the side." Students choose their own projects and form teams based on personal interest and share their work in Wiki-based course information environments. We are actively pursuing this research with the support of a project supported by the NSF-CISE "Creativity and IT" Program entitled *"A New Generation Wiki for Supporting a Research Community in Creativity and IT"* in which we (1) examine how current wiki-like environments are limited; (2) analyze and create specifically additional objects (such as mind maps, videos, anecdotes, and stories); (3) explore different modes interacting with such an environment (including: face-to-face activities, synchronous, asynchronous); and (4) utilize new paradigms (such as meta-design) for developing systems that are open and extensible.

Conclusions

The CSCL community can and should explore, design, and assess new *transformational conceptual frameworks for learning and education.* New media and new technology provide new exciting possibilities to rethink learning, teaching, working, and collaborating. Almost all serious educational reformers believe that new media and new technology on their own cannot transform learning to meet the demands of the future. Technology is only one part of the necessary cultural change. Cultural change implies that all stakeholders participating in the process of change have to reflect and change their behaviors, their objectives, and their values.

Some of the themes and challenges for future CSCL research articulated briefly in this article focused on: how can we help people of all ages learn to think and act more creatively; how can we help people develop mindsets for acting as active contributors in reflective communities that are key to creativity; and how can we create socio-technical environments grounded in these objectives?

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Mice, Minds, and Society

Symposia

Evaluating the Quality of Dialogical Argumentation in CSCL: Moving Beyond an Analysis of Formal Structure

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Abstract: Over the last decade, researchers have developed sophisticated online learning environments to promote argumentative discourse between students. This symposium examines some of the diverse ways researchers have attempted to examine how students engage in argumentation and to assess the effectiveness of CSCL environments in fostering productive argumentation. The papers presented as part of this symposium will focus on four different categories of analytic frameworks: (1) nature and function of contributions within the dialog, (2) nature of reasoning, (3) conceptual quality, and (4) patterns and trajectories of participant interaction. Example analytic frameworks from each category are presented in detail rich enough to illustrate their nature and structure. Synthetic discussions of each category consider the frameworks in light of the underlying theoretical perspectives on argumentation, pedagogical goals, and online environmental structures.

Supporting and Promoting Argumentation in CSCL Environments

Online learning environments that engage and support students in dialogic argumentation provide excellent opportunities for students productively to propose, support, evaluate, critique, and refine ideas. Over the last decade, a number of sophisticated environments have been developed to support students engaging in this type of knowledge-building discourse. Measuring the nature and quality of the dialogic argumentation that takes place within these environments, however, has proven challenging. This is due in part, to the context-specific nature of argumentation (Andriessen, Baker, & Suthers, 2003). As a result, argumentation quality cannot be defined solely on the basis of *what it is;* it must also be defined by *what it is used for, who does it,* and *how it unfolds*. Thus, in order to facilitate research and the development of new CSCL environments, the papers presented as part of this symposium highlight the foci, affordances, and constraints of several different analytic methods for assessing dialogic argumentation that are currently available to researchers. In addition to providing an overview of available methods, a major goal of this symposium is to highlight the benefits and limitations of using the different frameworks for assessing the quality of argumentation in different contexts. The different contexts that we will examine include: (a) the object (or subject) of the discussion, (b) the purpose for engaging in the discussion (e.g., to persuade or to co-construct a better solution), (c) the norms that will govern how participants will distinguish between ideas (e.g., fit with evidence or plausibility), and (d) the medium (the types of tools that have been incorporated into the environment to support argumentation).

Analytic Frameworks Presented

Early work measuring students' argumentation within CSCL environments relied heavily on analytic frameworks that emphasized argument structure and the presence or absence of different structural components of an argument as a way to assess quality (e.g., Toulmin, 1958). However, over the last decade, researchers interested in supporting and promoting argumentation as part of CSCL environments have developed a broad range of methods to assess the nature or quality of dialogic argumentation that better reflect the context-specific nature of argumentation. These methods have enabled researchers to focus on specific aspects of argumentation and to evaluate the impact of specific pedagogical goals or tools as a way to foster productive argumentation in CSCL environments. In order to facilitate the comparison of these analytic frameworks, all of the papers presented as part of this symposium evaluate the same short segment of student argumentation (see Table 1). The students in the example are arguing within a customized asynchronous threaded discussion forum about their interpretations of the data they have collected in an earlier part of the project (Clark & Sampson, 2005). At the heart of their argument is the scientific principle of thermal equilibrium.

Table 1: A short sample of dialogical argumentation to facilitate comparisons.

Individual	Comment
Fran:	I think objects in the same room remain different temperatures because some objects are good conductors and some are bad. This determines how much heat energy is allowed in and out of the object.
Amy:	I disagree; I think all objects in the same room are the same temperature. Conductivity only determines how quickly an object will reach room temperature.
Fran:	No, good conductors let in more heat energy than poor conductors, so objects that let in more heat will get hotter. For example, when I put a piece of metal and a piece of plastic in hot water the metal was a higher temperature after 30 seconds.
Amy:	I guess you're right. Maybe objects are different temperatures.

How should researchers of CSCL environments interpret our student example in terms of argumentation quality? In answering this question, researchers must choose a valid and reliable analytic method that (a) takes into account the context-specific nature of argumentation and (b) is compatible with their theoretical perspectives on argumentation, pedagogical goals, and the structure of their online learning environment. For example, researchers interested in promoting argumentation where individuals attempt to negotiate meaning by "proposing and accepting information in an effort to modify and build on each other's knowledge" are likely to adopt different pedagogical goals and online structures than researchers who are trying to promote argumentation where individuals attempt to "convince each other of their own viewpoint" (Andriessen, Erkens, Van de Laak, Peters, & Coirier, 2003, p. 82). These differences not only influence the nature of the argumentation that takes place between the participants in a CSCL environment but also affect what counts as a productive conversation.

The analytic methods discussed in this symposium were chosen to represent a range of promising approaches for analyzing dialogic argumentation in online learning environments. The selection process focused on each method's capabilities for assessing dialogic argumentation within online environments independent of whether or not the method had been originally developed for application in online or offline environments. As previously mentioned, the categories of analytic focus include (1) nature and function of contributions within the dialog, (2) nature of reasoning, (3) conceptual quality, and (4) patterns and trajectories of participant interaction. Each of the papers presented in this symposium focuses on one of these categories and uses the example of dialogical argumentation provided above to illustrate the constraints and affordances of the different frameworks. Each paper then concludes with a discussion of the suitability of the frameworks for examining the quality of argumentation in different contexts. The purpose of this discussion is not to identify some frameworks as being "better" than others; rather it is intended to provide researchers with a way to choose a framework that is compatible with their theoretical perspectives on argumentation, pedagogical goals, and the structure of their online learning environment.

Analytic Frameworks that Focus on the Nature and Function of Contributions within a Dialog in CSCL Environments

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Analytic frameworks that focus on the nature and function of participants' contributions examine the types of dialog in which students engage as well as the proportion of conceptually and argumentatively productive dialog. An example of this type of framework has been developed by deVries, Lund, and Baker (2002) to examine ways to promote epistemic dialogue in online learning environments. As defined by deVries, Lund, and Baker, epistemic dialog (1) takes place in a collaborative problem-solving situation, (2) can be characterized as argumentation or explanation, and (3) concerns the knowledge and concepts underlying the problem-solving rather than the execution of problem-solving actions. The analytic framework specifies four main categories (*explanation*, *argumentation*, *problem resolution* and *management*) subdivided in a total of 13 different coding categories. To foster epistemic discourse between students, deVries, Lund, and Baker integrate *structures that promote collaboration*, *asynchronous communication*, *dynamic visualizations*, *socio-cognitive structuring*, and *awareness heightening tools* into the CONNECT environment. In this environment, students work together in order to produce a piece of text that explains a puzzling phenomenon through a process of collaboration and negotiation.

Another example of this type of framework is *Rainbow*. Rainbow, which was developed by Baker, Andriessen, Lund, van Amelsvoort, and Quignard (submitted) to analyze computer-mediated pedagogical debates, comprises seven principal analytic categories. The primary focus is on the epistemic nature of the contributions that students make during collaboration. The framework was developed to allow the researchers to investigate what it means for participants to achieve conceptually deeper levels of interaction. At the most basic level, the Rainbow framework distinguishes between *assignment-related activity* and *outside-activity* (any interaction that is not concerned with carrying out the prescribed task). From there, Rainbow differentiates assignment related activity as either task-focused or non task-focused. Non task-focused activity is categorized as either *social relation* (interaction that is concerned with managing students' social relations with respect to the task) or *interaction management* (interaction concerned with managing the interaction itself). Task-focused activity is categorized as *task management* (management of the progression of the task itself), *opinions* (interaction concerned with expressing opinions with regard to the topic under debate), *argumentation* (expression of arguments and counterarguments directly related to a thesis), and *explore and deepen* (interaction concerned with arguments and counterarguments linked together, their relations, and the meaning of the arguments themselves including elaboration, definition, and extension). Baker and colleagues ground the rationale for each of these seven categories carefully in the research on collaborative learning, task-oriented dialogues, verbal interactions, and argumentation theory.

Janssen, Erkens, Jaspers, & Kanselaar (2006) have developed a *Dialogue Act* coding framework that focuses on the communicative instead of the epistemic nature of the contributions within a dialog. The framework first identifies the communicative function of each utterance typed by the students during their online collaboration and communication. The five main communicative functions include: *argumentative* (indicating a line of argumentation or reasoning), *responsive* (e.g., confirmations, denials, and answers), *informative* (transfer of information), *elicitative* (questions or proposals requiring a response), and *imperative* (commands). The framework specifies twenty-nine different dialogue acts within these five main functions. Seven of the twenty-nine focus on argumentative dialog. Dialogue Acts are recognized by specific 'discourse markers' that indicate the communicative function of the utterance, i.e. the use of the connective 'because' signifying an argumentative reason. The use of discourse markers facilitates the reliability of the framework in hand coding, but offers also the possibility of automatic coding.

Analysis of the Sample Argument

From the perspective of deVries, Lund, and Baker's framework, the example represents desirable epistemic discourse because all four contributions to the discussion can be characterized as either explanation or argumentation. As previously mentioned, de Vries, Lund, and Baker suggest that explanation and argumentation are "potentially powerful mechanisms by which students can collaboratively construct new meaning" (2002, p.64). Similarly, Janssen, Erkens, Jaspers, and Kanselaar's framework and Dialogue Act coding system indicates that the student example represents an extended sequence of argumentation and is therefore of high quality. The student example also represents quality argumentation from the perspective of the Rainbow framework because the example involves conceptual deepening and exploration of the topic.

Constraints and Affordances

Frameworks with a focus on the nature and function of contributions within the dialog focus by definition on ongoing discourse. They are therefore best suited for coding synchronous forums or asynchronous forums rather than environments focusing on the juxtaposition of a small number of crafted responses or the interpretation of dialogic artifacts. That said, however, frameworks such as Rainbow can be adapted to other formats as discussed by Baker and colleagues. Of the three frameworks discussed, de Vries, Lund, and Baker's framework is noteworthy for its consideration of the types of discourse moves that students may make; the Rainbow framework is grounded theoretically and is parsimonious enough to simplify application and analysis. Both focus on the epistemic nature of task-oriented discourse. Janssen, Erkens, Jaspers, and Kanselaar's framework focuses on the communicative nature of task-oriented discourse and offers potential in terms of its automated capabilities, but is inappropriate for judging the quality of contributions. In sum, these frameworks provide different approaches for researchers interested in assessing the nature of student's contributions and the overall effectiveness of online environments designed to encourage substantive discussions about the knowledge and concepts underlying problem solving. An overview of the suitability of these three frameworks for assessing argumentation in different contexts is provided in Table 2.

Table 2: Suitability of the analytic frameworks that focus on the nature and function of contributions

Framework	Nature of the Argumentation: Subject of the Discussion			Goal of the Discussion			Rules for Judging Ideas			Medium: Tools used in the Environment					
	Well defined problem with one solution	Complex problem with multiple solutions	Wicked problems with no right answer	Reach consensus or persuade others	Learn more about the topic	Develop a solution	Empirical	Plausibility or Logic	Moral or ethics	Easily accessible and accessed information	Asynchronous communication	Representations of subject matter	Dynamic visuals of student arguments	Socio-cognitive structuring	Awareness heightening tools
deVries, Lund, & Baker (2002): Epistemic Dialog	••	•••	•••	••	•••	•••	••	••	••	••	••	••	••	•	••
Baker et al. (submitted): Types of Contributions	•••	•••	•••	••	•••	••	••	••	••	••	••	••	••	•	••
Janssen et al. (2006): Dialogue Acts Scoring	••	•••	•••	••	•••	••	•	•	•	••	•••	••	••	•	•••

Note: ••• indicates that the framework is well suited for use in this context, •• indicates that this framework can be used in this context but provides no specific affordances, • indicates that the framework may be inappropriate for this type of context without some modification

Analytic Frameworks that Focus on the Nature of Reasoning during Argumentation in CSCL Environments

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Analytic frameworks that examine the epistemic nature of students' reasoning focus on the types of reasoning students use to support their claims or to challenge the claims of others. Both Jimenez-Aleixandre, Rodriguez, & Duschl (2000) and Duschl (2000) have developed analytic methods designed to address this question using Walton's (1996) argumentation schemes for presumptive reasoning as a theoretical framework. Walton suggests that dialectical argumentation is grounded in burden of proof, presumption, and plausibility rather than in structural form alone. Walton details twenty-five different argumentation schemes that focus on how presumptions are brought forward in arguments as kinds of premises or as kinds of inferences that link premises to conclusions in a context of argumentative dialog. Examples of these schemes include an argument from evidence to hypothesis (e.g., the data we gathered indicates…) and an argument from analogy (e.g., this is just like…). The function of these schemes is to shift the weight of presumption from one side of a dialog to the other. An opposing voice can then respond with questions or statements that shift the weight of presumption back upon the original participant. Analysis with this type of framework focuses on categorizing the types of reasoning employed within an argument.

Jimenez-Aleixandre, Rodriguez, & Duschl's framework apply a standard Toulmin model (e.g., data, warrants, and qualifiers) to identify instances when students attempt to support their ideas during small group and whole class discussions. Once these instances are identified, they examine *how* students elaborate, reinforce, or oppose the ideas of each other by classifying claims and warrants using epistemic operations based on Walton's categories of presumptive reasoning. Analysis then compares the proportion of these instances to the total about of dialog and the types of epistemic moves that are most often used during the discussion or debate. More recently, Duschl (in press) has developed an innovative way to apply Walton's framework to scientific argumentation in the classroom. Duschl first narrows Walton's twenty-five categories down to the nine categories that they found to have strong relevance to scientific argumentation in the classroom. Distinguishing between even these nine categories, however, proves difficult in coding students' work. Duschl and his group therefore collapsed the nine categories into four categories including *requests for information*, *expert opinion*, *inference*, and *analogy*. They then apply these coding categories at the level of the reasoning sequence, which is approximately at the level of each of the students' comments in our example. Analysis then focuses on the number and proportion of each of these epistemic discourse types in students' discussions.

Analysis of the Sample Argument

The potential benefits of examining the epistemic nature of contributions to a discussion or debate become evident when the student example is analyzed using Jimenez-Aleixandre et al. and Duschl's frameworks. Rather than simply documenting that the students are making claims and supporting their ideas with data, warrants, or qualifiers, these frameworks enable us to identify the nature of their reasoning. For example, Jimenez-Aleixandre et al's framework suggests that these students are attempting to justify their ideas with reasons that focus on causality, consistency, and appeals to instances rather than relying on plausibility or appeals to authority. Similarly, Duschl's framework suggests that the students are relying on desirable epistemic moves such as inferences from evidence to hypothesis (the metal was a higher temperature after 30 seconds) and inferences from cause to effect (conductivity determines how quickly an object will reach room temperature) in order support or refute an idea. The student example therefore represents fairly high quality argumentation from the perspective of these frameworks.

Constraints and Affordances

Frameworks that focus on the epistemic nature of reasoning are designed to provide valuable information about how students determine 'what counts' as warranted knowledge and how students determine which ideas should be accepted, rejected, or modified. Rather than assessing conceptual quality of students' contributions, this focal category revolves around the types of reasoning that students use when they propose, support, evaluate, and challenge ideas. In terms of specific affordances and constraints, Jimenez-Aleixandre, Rodriguez, & Duschl's framework is valuable because it integrates an assessment of reasoning type with structural quality. In practice, however, differentiating between students' epistemic operations can prove difficult, but this framework's consideration of the nature of students' reasoning and argumentation structure may prove particularly fruitful for those interested in scaffolding students as they engage in argumentation. Duschl's framework, in turn, is noteworthy for its distillation and synthesis of Walton's framework into a manageable discipline-specific coding scheme.

Overall, these frameworks (and this categorical focus for analysis) apply well for those interested in helping students to improve their discourse skills, reasoning, and ability to evaluate arguments by helping students learn specific discourse goals (e.g., securing commitments from an opponent or undermining the opponent's argument) and effective strategies to help them meet these goals (e.g., justifying claims with evidence, requiring opponents to justify their claims with evidence). These frameworks also are applicable to almost any type of environment structure because they focus on a core attribute of all argumentation. Generally speaking, they focus on frequency counts so they are better suited to environments supporting free flowing dialog, such as asynchronous and synchronous discussions rather than the micro analysis of smaller segments. One advantage of this categorical focus, however, involves the relative content independence afforded in comparison to frameworks focusing specifically on the conceptual quality of ideas. Frameworks focusing on the epistemic nature of reasoning therefore require little modification when applying them across related topic areas. An overview of the suitability of these two frameworks for assessing argumentation in different contexts is provided in Table 3.

Table 3: Suitability of the analytic frameworks that focus on the nature of reasoning

	Nature of the Argumentation														
	Subject of the Discussion			Goal of the Discussion			Rules for Judging Ideas			Medium Tools used in the Environment					
Framework	Well defined problem with one solution	Complex problem with multiple solutions	Wicked problems with no right answer	Reach consensus or persuade others	Learn more about the topic	Develop a solution	Empirical	Plausibility or Logic	Moral or ethics	Easily accessible and accessed information	Computer mediated communication	Representations of subject matter	Dynamic visuals of student arguments	Socio-cognitive structuring	Awareness heightening tools
Jimenez-Aleixandre et al. (2000): Structure and Nature of Reasoning	••	••	••	••	••	••	•••	•••	••	••	••	••	•	•	•
Duschl (in press): Application of Walton to Dialogic Argumentation	••	••	••	••	••	••	•••	•••	••	••	••	••	•	•	•

Analytic Frameworks that Focus on Conceptual Quality in CSCL Environments

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Analytic frameworks that focus on *conceptual quality* examine the content or substance of the contributions that are made during a discussion. Clark and Sampson's framework (2005), for example, focuses on analyzing the relationships between levels of opposition that take place during discourse episodes and the nature, conceptual quality, and grounds quality of constituent student contributions. Kuhn and Udell's (2003) framework, on the other hand, focuses on the logical coherence and the relevance of the arguments generated by students as a way to measure the conceptual quality of the ideas proposed by students. The content component is domain-specific, involving specified hierarchical sets of arguments for (pro) and against (con) the topic being debated (which is capitol punishment in their study). The lowest level comprises *Nonjustificatory Arguments*, which have little or no argumentative force. The middle tier comprises *Nonfunctional Arguments*, which focus on tangential aspects of the problem rather than core issues. At the highest level, *Functional Arguments* address core aspects of the problem. This type of focus is especially well-suited for online environments where students' are encouraged to debate and discuss issues without clear "right" or "wrong" answers (such as capital punishment). In addition to these dialogic-oriented frameworks, excellent rhetorical-oriented frameworks by Sandoval and others exist.

Analysis of the Sample Argument

The application of Clark and Sampson's framework to the example of argumentation indicates the discourse is oppositional in nature because it involves a distinct rebuttal against the grounds of an idea as well as a rebuttal against the thesis of an idea. However, in terms of conceptual quality the argumentation is considered poor because the students reach an inaccurate conclusion. Moreover, this episode illustrates how students can distort evidence to match claims. In this example, Fran convinces Amy to abandon her normative idea that objects sitting in the same room are in thermal equilibrium by providing inappropriate evidence in support of a non-normative idea. From the perspective of Kuhn and Udell's framework, we would view the example as exceedingly short but representing quality argumentation. The arguments presented by Fran and Amy are *functional* in terms of conceptual quality, which indicates that these students address key aspects of the problem. Moreover, the discourse moves used by the students in this example heavily emphasize argumentative moves (e.g., challenging the ideas of others) rather than exposition (e.g., proposing or clarifying one's own ideas).

Constraints and Affordances

Overall, the analytic frameworks that focus on conceptual quality are well-suited for online-environments for those interested in the relationship between argumentation and learning. For example, when the pedagogical goal of an online environment is to help students learn how to engage in argumentation (e.g., proposing, justifying, and challenging ideas), the analytic framework can focus on the structure of students' contributions to the discussion and still be sufficient. However, if the goal of the online environment is to provide an opportunity for students to learn from argumentation (e.g., develop a more in-depth understanding of the content that is being discussed), the analytic framework must also be able to examine the normative quality of students' ideas in order to assess the overall effectiveness of the environment. In choosing an analytic framework, researchers must determine the importance of the relationship between the normativity of a comment and the relative time of its contribution. Non-normative content at the onset of dialog followed by increasing normativity by the conclusion of the dialog might represent something entirely different than the reverse trajectory. Kuhn and Udell address the temporal issue by measuring the normativity of students' arguments before and after the dialog, for example, but do not examine the trajectories within the dialog itself.

A focus on conceptual quality of contributions or products fits well with environments that include easily accessible and indexed knowledge bases and enriched representations of focal subject matter because these types of functionalities are often integrated into online environments designed to help students achieve specific content learning goals that are associated with the databases and enriched representations. In addition, environments that integrate asynchronous communication and awareness heightening tools can also benefit from this type of focus. By examining the content of student ideas and how students interact with each other, researchers can better support students as they attempt to negotiate meaning or validate ideas in online environments. One challenge, however, is that rubrics with a focus on normativity become very topic-specific and thus require significant modification for application across contexts. An overview of the suitability of these two frameworks for assessing argumentation in different contexts is provided in Table 4.

Table 4: Suitability of the analytic frameworks that focus on conceptual quality

	Nature of the Argumentation														
	Subject of the Discussion			Goal of the Discussion			Rules for Judging Ideas			Medium Tools used in the Environment					
Framework	Well defined problem with one solution	Complex problem with multiple solutions	Wicked problems with no right answer	Reach consensus or persuade others	Learn more about the topic	Develop a solution	Empirical	Plausibility or Logic	Moral or ethics	Easily accessible and accessed information	Computer mediated communication	Representations of subject matter	Dynamic visuals of student arguments	Socio-cognitive structuring	Awareness heightening tools
Clark & Sampson (2005): Conceptual Quality of Comments	•••	•	•	•••	••	•	•••	•	•	•••	•••	•••	•	•	••
Kuhn & Udell (2003): Argumentation Quality and Types of Comments	••	•••	•	•••	•••	•	••	•••	••	•••	•••	••	•	•	•

Analytic Frameworks that Focus on Patterns and Trajectories of Participant Interaction during Argumentation in CSCL Environments

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Analytic frameworks focusing on patterns and trajectories of participant interaction consider argumentation as a primarily social activity. Examples of frameworks with that focus are Leitão (2000), Hogan, Nastasi, and Pressley (2000), Baker (2003), and Weinberger and Fischer (2006). Leitão (2000) considers a specific sequence of argumentation to be particularly fruitful for knowledge building. Based on Piaget's (1985) work and his idea of socio-cognitive conflict, Leitão envisions argumentation as a social activity in which students confront each other with opposing views and build knowledge by resolving this conflict in a specific manner. In what Leitão calls a knowledge building cycle, students (1) construct an *argument*, which consists of a position and its justification, (2) construct a *counterargument* in response to the first argument, and (3) create a *reply* that captures the participants' immediate and secondary reactions to the counterargument. Through these patterns of argumentation, the initial arguments may be preserved, revised or withdrawn. Leitão argues that these patterns of argumentation optimally shape the process of social knowledge construction.

Hogan, Nastasi, and Pressley's (2000) framework examines discourse components, interaction patterns, and reasoning complexity. The framework focuses on (1) how students work to improve weak or incomplete ideas, (2) the patterns of verbal interactions that take place between individuals in scientific sense-making activities, and (3) the relationships between discourse patterns and the sophistication of scientific reasoning in discussions. Analysis begins with the assignment of macro-codes to the major modes of a group's discussion at the level of conversational turns. Macro-codes include *Knowledge Construction*, *Logistical*, and *Off-Task*. Micro-codes are then assigned at the level of statement or phrase including *Conceptual*, *Metacognitive*, *Question-Query*, *Nonsubstantive*, and *Other*. Micro-codes include multiple subcategories. Researchers then create discourse maps illustrating the patterns of interactions between students based on these codes. Patterns of interaction include *consensual* (where a student proposes an idea and another student agrees), *responsive* (where a student asks a question and another student answers), and *elaborative* (where students discuss and revise each others ideas). Researchers next assess reasoning complexity and compare this information to the interactional patterns.

Baker's framework examines the standpoints adopted by individuals during argumentation, how ideas change over time, and the pragmatic function of language. The framework focuses on argumentation as a way to facilitate collaborative learning. According to the framework, argumentation transforms the epistemic status of solutions by establishing relations between the proposed solutions and other knowledge or by promoting the negotiation of new meaning. The epistemic status indicates to what extent solutions are being approved. Arguments strengthen the epistemic status of a solution. Counter-arguments weaken the epistemic status of a solution. As a discursive activity, argumentation establishes relations between possible solutions and other sources of knowledge. As a dialogic activity, argumentation incorporates aspects of formal and pragmatic dialectics. Through the analyses, this framework measures the strengthening and weakening of the epistemic status of various claims as well as the progression of dialectic moves.

Weinberger and Fischer's (2006) framework examines the process through which knowledge is constructed as students engage in argumentation in online environments. Their framework assesses argumentation along four independent dimensions. The *participation dimension* analyzes the amount of participation by each student and the heterogeneity of participation within the learning group. The *epistemic dimension* identifies how and what theoretical concepts students use in their argumentation them in terms of the environment's learning goals. On the *formal argumentative dimension*, Weinberger and Fischer analyze the construction of single arguments through a simplified version of Toulmin's scheme (1958) as well as through the argumentation sequences outlined in Leitão's (2000) work. Finally, on the *dimension of social modes of co-construction,* Weinberger and Fischer analyze the transactivity of students' arguments (Teasley, 1997), i.e. to what extent students refer to the arguments and operate on the reasoning of their learning partners. Different ways to build consensus correspond with different degrees of transactivity. Students can establish consensus by agreeing with the ideas proposed by their peers (relatively low transactivity), integrating peers' arguments into their own line of argumentation (relatively high transactivity), or by engaging in a conflict-oriented negotiation of different perspectives (relatively high transactivity).

Analysis of the Sample Argument

From the perspective of Leitão's framework, our student example represents a complete knowledge building cycle. The episode begins with Fran contributing her initial argument. Amy then counters by bringing the truth of the claim into question. Fran replies by dismissing Amy's counter argument which enables Fran to preserve her initial viewpoint. In this case, Amy accepts Fran's ideas and withdraws her initial viewpoint. From Leitão's perspective, both this type of outcome and outcomes that result in a revised argument represent successful outcomes of argumentation. Hogan, Nastasi, and Pressley's framework would describe the sample argument as an *elaborative* interaction pattern. They suggest that elaborative interaction patterns are characteristic of quality argumentation because they prolong discussions and lead to higher levels of reasoning. Although there is no elaboration present, the student example's macro-code represents Knowledge Construction from the perspective of this framework. The example also represents fairly high quality argumentation from the perspective of Baker's framework. Although brief, the discourse changes the epistemic status of Idea A (objects remain different temperatures) and Idea C (objects become the same temperature) which indicates productive argumentation. Applying Weinberger and Fischer's framework shows that the learners participate homogeneously (*participation dimension*). With respect to the *epistemic dimension*, both Fran and Amy engage in on-task talk and construct relations between the target conceptual space (rather than prior knowledge) and the problem space. However, some of the concepts are being applied inadequately. On the *formal argumentative dimension*, Amy and Fran build relatively complete arguments and argumentation sequences. Finally, on the *social modes of co-construction dimension,* Amy and Fran clearly engage in conflict-oriented consensus building as they refer to each other's contributions and attempt to negotiate meaning.

Constraints and Affordances

This analytic category increases the unit of analysis from an individual comment or fragment to an entire knowledge building cycle. As such it allows us to focus on the actual processes of co-construction of knowledge rather than focusing on frequency counts of elements that correlate to desirable interaction. Leitão, for example, emphasizes the social nature of knowledge building as opposed to online contexts in which students hardly interact with the activities of their learning partners (e.g., by composing elaborate, essay-like replies in discussion boards). This approach thus emphasizes the coherence of argumentative talk between students. One interesting dichotomy, however, involves the presence or absence of a pedagogical goal state within the framework to inform the development of practice. In other words, does the framework provide a road map for instruction in terms of desirable student practice? For example, Baker's analytic framework provides ways to track the evolution and change in status of the ideas discussed by students and how (or if) they are challenged, but the framework provides us less concrete guidance for instruction. What do we want students to know or to be able to do? Other frameworks are more prescriptive in this regard. Weinberger and Fischer (2006) have applied different kinds of computer-supported collaboration scripts to successfully facilitate learners' interaction with respect to the single dimensions of their framework. Their line of research indicates that especially scripts that facilitate transactivity of learners in CSCL environments, have also facilitated individual knowledge acquisition (Weinberger, Stegmann, Fischer, & Mandl, in press).

This type of analytic focus may be applied across most collaborative online argumentation environments independent of environment structure or the nature of the artifacts created, because this analysis can focus at microgenetic scales as well as broad scales. Increased complexity of application accompanies this increased power, however. The challenge of this analytic category manifests itself in terms of increased amount and complexity of work required to reliably apply these types of analyses across larger samples. An overview of the suitability of these four frameworks for assessing argumentation in different contexts is provided in Table 5.

Table 5: Suitability of the analytic frameworks that focus on patterns and trajectories of participant interaction

	Nature of the Argumentation														
	Subject of the Discussion			Goal of the Discussion			Rules for Judging Ideas			Medium Tools used in the Environment					
Framework	Well defined problem with one solution	Complex problem with multiple solutions	Wicked problems with no right answer	Reach consensus or persuade others	Learn more about the topic	Develop a solution	Empirical	Plausibility or Logic	Moral or ethics	Easily accessible and accessed information	Computer mediated communication	Representations of subject matter	Dynamic visuals of student arguments	Socio-cognitive structuring	Awareness heightening tools
Leitão (2000): Knowledge Building	••	•••	•••	•••	•••	•••	••	••	••	••	•••	••	•	•	•
Hogan et al. (2000): Interactional Patterns	•••	•••	••	•••	••	••	••	••	••	••	•••	••	•	•	•
Baker (2003): How ideas change	••	•••	•••	•••	•	•••	••	••	••	••	•••	••	•	•	•
Weinberger & Fischer (2006): Co-construction of knowledge	••	•••	••	•••	•••	•••	••	•	•	••	•••	••	•	•••	•

Synthesis

In this symposium we consider several frameworks for analyzing dialogic argumentation in online learning environments. These analytic frameworks vary significantly in terms of their focus and affordances. (Each presenter in our symposium will go into greater detail about each focal category.) Although most of the frameworks discussed here would assess the student example as representing fairly desirable argumentative discourse, they each do so for very different reasons. In building online environments to support argumentation, researchers therefore need to be clear and specific in terms of their theoretical commitments about argumentation and the pedagogical goals they wish to foster (and concomitantly measure) through the environment. These decisions are foundational in the subsequent adoption or development of an appropriate analytic framework.

Another issue that becomes apparent when reviewing these frameworks involves the potential to synergistically integrate multiple categories of analytic focus within a single framework. Although each paper in this symposium examines a single focal category, all of the frameworks consider additional foci beyond their focal categories. By coordinating the analyses of multiple categories simultaneously, we can potentially learn more about students' performance in terms of each individual category. Integrating other analyses within the analysis of the patterns and trajectories of participant interaction seems the most promising. Most of the other categories of analytic focus correlate frequency counts of various components as correlational markers for argumentation quality. Careful tracking of participant interaction and the evolution of ideas would align our analyses more directly, and therefore potentially more validly, with the processes of argumentation we wish to foster. The challenge, of course, rests in the increased accompanying complexity of conducting such analyses.

Online learning environments offer strong affordances for grappling with these challenges and realizing these gains. Online learning environments incorporate the potential to closely log students' actions and interactions. As we develop technologies to more carefully track and analyze student data, we will have the capability to track interactions and quality more accurately in real time. Based on this information, we could then modify supports for argumentation in real time. Dönmez, Rosé, Stegmann, Weinberger, and Fischer (2005) have made early progress in this regard by harnessing latent text analysis technology to score the quality of students' argumentation products. Similarly, the Multiple Protocol Episode Analysis system (Janssen, Erkens, Jaspers, & Kanselaar, 2006) can score extended dialogs and messages using a complex rules system instantaneously. In both of these examples, analyses were not conducted in real time, but the potential is staggering. As we develop more sophisticated methods for analyzing argumentation, we should therefore continue to monitor the possibilities for embedding these analytic methods directly as real time functionality within online learning environments. These analytic models would therefore not only improve our research capabilities but also facilitate higher levels of interactivity and customized scaffolding for students engaging in argumentation in our schools. The discussion at the conclusion of our symposium will also consider the implications of the frameworks beyond research in terms of these other applications.

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Fostering Peer Collaboration with Technology

Introduction

In this symposium we address recent developments in learning environments, including logging, data mining, authoring, and collaboration tools that have opened new doors for research. In particular we present projects that afford logging students' data in a very fine-grained way and data mining techniques to characterize students' learning beyond their mouse clicks. These systems have enhanced our ability to support students in collaboration while learning and well as track students' collaboration. Gobert's paper will discuss a collaborative learning study focused on collaborative model-building and peer critique which used the WISE infrastructure. Slotta's paper will present a new generation of a technological infrastructure, SAIL, which is based on WISE and logging from the Concord Consortium. The paper by Clarke and Dede will focus on data mining of rich data while students used the River City MUVE Environment. The paper by Gijlers et al will address the interaction between the tools used for inquiry and students' inquiry processes. Lastly, the paper by Koedinger will present methodologies, etc., developed by the Pittsburgh Science of Learning Center (PSLC) which support data collection and analysis in order to contribute to what we know about "robust learning".

Many of the papers will focus on data mining since it offers a potentially powerful analytic framework for many educational interventions that generate rich data sets and data-streams about student learning. For example, text mining analytics could aid in identifying patterns in the explanations and critiques of the two thousand students engaged in WISE model-based activities described in Gobert et al. Gijlers et al could conduct similar analyses on the text generated by their chat tool, looking for patterns related to argumentation, collaborative reasoning, and elaboration. The SAIL scalable architecture Slotta describes could provide a common framework for structuring the databases on which various researchers conduct data mining. The PSLC LearnLab testbed illustrates the type of venue that could generate the large amounts of data and substantial numbers of students for which data mining is particularly powerful and appropriate. In recognition of this, research using data mining is already taking place in the intelligent tutoring systems community.

Collectively, these projects represent advances to this area of research offering the following affordances: (1) *data collection,* such that they afford accurate capture of students' actions; (2) *authoring and customization*, which enables researchers to develop, and teachers to tailor curriculum materials that target research questions or student populations; (3) *tracking*, which allows materials and assessments to be accurately managed, versioned, etc.; (4) *integration*, which enables materials to be seamlessly incorporated into instruction; (5) *reach*, which enables researchers to conduct studies anywhere, collect data automatically, and easily make updates to materials for any school worldwide; and 6) *open source,* namely, that since many of these technologies are interoperable and open-source, dynamic development and rapid evolution are possible.

In this one and a half hour symposium, there will be a short introduction to the session followed by a presentation of each project. Dr. Dan Suthers will then serve as a discussant for the session. Dr. Suthers is presently Associate Professor in the department of Information and Computer Sciences at the University of Hawai`i at Manoa, where he directs the Laboratory for Interactive Learning Technologies (http://lilt.ics.hawaii.edu) and co-directs Hawai`i Networked Learning Communities (http://hnlc.org). His research is generally concerned with technology-supported collaborative learning and online learning communities, with applications to K-12, university and professional development contexts, making him an ideal discussant for this symposium. Dr. Suthers obtained his M.S. (1988) and Ph.D. (1993) degrees in Computer Science from the University of Massachusetts. Subsequently he worked at the Learning Research and Development Center of the University of Pittsburgh before coming to the University of Hawai`i.

Fostering collaborative model-building and peer critique on-line

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Model-based teaching and learning (Gobert & Buckley 2000) is an effective cognitive and pedagogical framework for scaffolding students' understanding of complex science domains such that the various components of the domain, i.e., the spatial, causal, and temporal features can be successfully integrated into rich mental models (Gobert, 2000). Peer collaboration has also been found to be a successful strategy for deepening and promoting students' knowledge building in many different disciplines (cf. Scardamalia & Bereiter, 1994; Gobert & Pallant, 2004). In this project, these two powerful pedagogical approaches are combined, namely model-building, and peer collaboration, in order to evaluate the efficacy for students' learning and characterize the affordances of this rich form of peer collaboration.

Two thousand middle and high school students from demographically diverse schools in California and Massachusetts collaborated on-line about plate tectonic activity in their respective location using WISE, Web-based Inquiry Science Environment (Linn, 1998). The curriculum engaged students in many inquiry-oriented, model-based activities which relied heavily on peer collaboration. For example, students were scaffolded in WISE as they: a) drew initial models of plate tectonic phenomena in their respective area using WISE; b) wrote explanations of their models and shared their models and explanations with students on the opposite coast (east vs. west); c) were scaffolded to critique their peers' models; d) revised their models based on this feedback; e) questioned their peers about plate tectonics on the opposite coast, and f) discussed the differences between E and W coast geology in an on-line forum. Previous analyses on this project have focussed on measuring content gains and epistemological gains for which significant gains for were found for both (Gobert & Pallant, 2004). Additionally, analyses of a small subset of data illustrated the nature of model revisions which students made on the basis of their peers' critique. For this presentation, a deeper analyses of the students' model revisions, peer critiques, and peer questions will be presented in order to provide a context for undertstanding more deeply how peers can influence knowledge building and model revision.

Supporting Collaborative Inquiry: New Architectures, New Opportunities

James Slotta
University of Toronto

This paper will present recent progress in an open source technology framework that enables the development, exchange and interoperability of richly interactive learning materials. Building on ten years of success in the Web-based Inquiry Science Environment (WISE), but also responding to key limitations in the WISE technology architecture, Slotta and his colleagues have created a new Scalable Architecture for Interactive Learning (SAIL). SAIL enables the design and development of java-based learning content, with the goal of supporting an international open source exchange community. Departing from the server-client architecture of WISE, inquiry curriculum is distributed as a peer-to-peer network of local hosts that serve classrooms, schools and districts. Next-generation learning environments will be able to utilize the full functionality of student computers, benefiting from the strength of locally hosted networks and peer-to-peer functionality. Expanded functionality will emphasize Java-based modules that support a diversity of user experiences, including models and simulations such as those developed by other cognitive and educational researchers. For example, the European CoLab project will be integrated into a SAIL framework, allowing multi-user CoLab modules to be supported in a scaffolded learning environment similar to WISE. SAIL will enable a greater range of user interfaces (e.g., immersive game- like interfaces, menu driven interfaces, or distributed, hand- held interfaces) as well as a wealth of user functionality for synchronous design spaces, online communities for teachers and mentors, or language learners and multilingual communities.

The paper will present an overview of SAIL, then discuss its implications for (1) the delivery of innovations to a broad audience, (2) the easy collection of user data (e.g., work done by students) for purposes of feedback and assessment, (3) the promotion of content communities (e.g., an earth science curriculum community) and (4) the support of an open source developer community across numerous projects that employ the SAIL architecture, leading to a greater dynamic evolution of our innovations, as well as interoperability across projects. Next, the paper will demonstrate a new wiki-based community for the learning sciences called the Community for Open Resource Exchange (CORE) that is currently supporting exchanges between numerous research labs. Finally, an early phase project will be demonstrated: the SAIL Smart Space: A configurable smart space capable of being shared as an open source research platform to enable studies of this important domain. SAIL Smart Space allows for the configuration of micro servers within a classroom, RFID nodes, and emphasizes curricular coherence across the following dimensions: physical space (i.e., within the 3 dimensions of the classroom, online, offline, at home, and on field trips); time (i.e., coordinating curriculum at all points of time and across numerous iterations); social context (i.e., supporting social groupings, jigsaws and exchanges); curricular space (i.e., various levels of variables, conditions, stages or other curricular phases). The paper will close with a discussion of the implications of open source research infrastructure for the learning sciences, particularly with respect to computer supported collaborative learning.

The River City MUVE

Jody Clarke, Chris Dede, Harvard University

As described in the National Research Council report, *Knowing What Students Know* (Pellegrino, Chudowsky & Glaser, 2001), sophisticated educational media now enable the collection of very rich datastreams about individual learners. For example, the River City MUVE has a customized 'plug-in server' that contains a data-tracking system. The data-tracking system allows us to collect, store, and retrieve information on the moment-by-moment movements, actions, and utterances of each student as they explore the River City MUVE environment. All items in the world that students can interact with have been tagged with identification codes. Every time a student clicks on a virtual object (picture, resident, sign, map, etc) or speaks to either a resident or teammate, the record is stored in a table in a relational database on the server. These data allow us to record the trajectory of each student as they work through the curriculum in the form of detailed log files—something that is not possible in traditional classroom practices. These log files provide extensive time-stamped records of where the students went in the world, what virtual objects they clicked on, who they talked to, and what they said.

We will share how we are using "data mining" techniques to make sense of our log file data and also present preliminary findings. "Data mining" is the process of selecting, exploring, and modeling large amounts of data to uncover previously unknown patterns (Gayle, 2000). The business world has been using this approach to identify patterns and behaviors of customers successfully for years (Gayle, 2000; Shaw, Subramaniam, Tan, Welge, 2001). Analyzing these rich datastreams of student participation using "data mining" can potentially yield formative, diagnostic feedback (Feng & Heffernan, 2005) and summative assessment (Hulshof, Wilhelm, Beishuizen, & Van Rijn, 2005) on student performance. It may also provide insights about complex patterns and dynamics of student behavior and learning (Ketelhut, Dede, Clarke, Nelson, & Bowman, in press) and collaborative problem solving and team learning processes (Avouris, Komis, Margaritis, & Fiotakis, 2004; Linton, Goodman, Gaimari, Zarrella, & Ross, 2003; Suthers & Hundhausen, 2003) that will be beneficial to the education community.

Interaction between tool and talk, how support for inquiry processes influences peer communication

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Various studies show that under specific conditions, collaboration can improve learning (Webb & Farrivar, 1999). This improvement depends strongly on the nature of peer interaction during collaboration (Webb, Nemer, & Zuniga, 2002). Elaborate responses and the extent to which students operate on the contributions of their peers (level of transactivity) are associated with positive learning outcomes (Teasley, 1997; Webb et al., 2002). Recently, researchers have started to investigate the combination of collaborative learning and inquiry learning and designed scaffolds to support the collaborative inquiry learning processes (Bell, 2004; Gijlers & de Jong, 2005; Saab, Van Joolingen, & Van Hout-Wolters, 2005). Traditionally, tools designed to support collaboration aim at supporting the communication between group members. However, guidance directed at the *processes of inquiry*, may indirectly influence group communication as well as support student learning gains.

The results presented in this study are based on a re-analysis of data from two research projects. The main objective of the re-analysis is to examine the relation between nature and quality of students' communicative processes and the characteristics of the different task related scaffolds. In both projects, secondary school students (approximately 16 years) worked, in dyads, with a simulation environment within a physics domain (collisions or one dimensional kinematics) and communicated through a chat tool. Students' chat discussions as well as their inquiry learning activities were logged. During their interactions with the learning environment students were supported through one of the following tools: 1) a shared hypotheses scratchpad, that was designed to facilitate the collaborative construction of hypotheses, 2) a shared hypothesis table, that confronted students with differences in their individual opinions about specific propositions and 3) a concept mapping tool, that allowed students to collaboratively build a representation of the relations within the domain. All scaffolds focused on the process of generating and discussing hypotheses but differed on concrete vs. abstract and directive vs. restrictive dimensions.

The scheme used to code students' chat communication distinguishes different communicative acts including various forms of argumentation, collaborative reasoning, and elaboration. Analysis of the coded discourse focuses on the characteristics of the student chat discourse in relation to the similarities and differences between the scaffolds. The results of a preliminary analyses of students' interaction suggests that the characteristics of the different scaffolds not only affected students' inquiry learning processes but also affected their communication and argumentation processes, more specially the level of transactivity and consensus building process. For instance, it was found that the more restrictive tool (the shared hypothesis table) resulted in less elaborate argumentation when compared to the more open tools, in which learners build more on each others arguments. In the symposium the full results will be presented.

The work by Gijlers, Saab, van Joolingen and de Jong is based on a re-analysis of log files of students' interactions with the learning environment (including tools) as well as students' chat communication. The re-analysis focused on the relation between the nature and quality of students' communicative processes and the characteristics of the inquiry learning environment students worked with. The information extracted from the log files showed that the characteristics of different scaffolds aimed at supporting the inquiry learning process also influenced collaborative learning process and students' communication. The results provide valuable input for the development of learning materials that stimulate collaborative reasoning and elaboration.

Technology Support for In Vivo Experiments on Collaboration and Metacognition

Ken Koedinger, Carnegie-Mellon University

The Pittsburgh Science of Learning Center (PSLC) is a 5-year center, $25 million funded by the US National Science Foundation (see learnlab.org). PSLC's main goal is to advance scientific understanding of "robust learning", learning that transfers to novel situations, is retained for long periods, and accelerates future learning. Toward that goal, we are creating technological resources that afford learning research: - faster and easier authoring of advanced educational technologies, - intelligent tutoring systems and on-line courses to run tightly-controlled experiments in classrooms, - technologies to collect fine-grained longitudinal learning data, - data sets available to researchers, - machine learning techniques for data mining. PSLC supports researchers around the world in making use of these resources in scientific investigations of robust learning. In particular, PSLC provides a means for researchers to run experiments in the context of one of seven technology-enhanced courses in math, science, and language learning. These full courses are in use in hundreds of high schools and numerous colleges and PSLC has arrangements with a number of these sites that allow tightly-controlled studies to be performed in the live context of these courses, that is, as "in vivo learning experiments". Current in vivo studies are exploring a wide range of issues including supporting collaboration within and around intelligent tutoring systems, supporting metacognition, learning from observation, forms of self-explanation. This talk will summarize results from some of these studies including evidence that collaboration scripting improves learning in the context of the Algebra Cognitive Tutor.

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Redefining learning goals of very long-term learning across many different fields of activity

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With
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Rogers Hall, Ken Wright, and Ka:ren Wieckert Vanderbilt University, Nashville, Tn. USA.

Abstract: There is a hidden agenda in our modern conception of learning—especially as embodied in education—that the learning experiences gained in one "learning situation" are naturally built-upon, expanded, and integrated with experiences from other learning situations. But we believe this implicit learning assumption has not yet been as substantially researched or discussed as is warranted by its importance. Furthermore, little support has been implemented. In this symposium, in accordance with the conference theme which encourages us to explore interrelations among individual and social cognition with technology, we would help illuminate this hidden agenda. We would take some closer looks at cutting-edge research on knowledge integration of learning outcomes from different classes, across formal and informal learning settings, and for longer time periods than usually taken up by learning science research. We would then propose to define a new set of learning goals as assuring the *portability*, *dependability*, and *sustainability* of learning outcomes.

As the newest "transfer strand" issue of the *Journal of the Learning Sciences* suggests, the field is expressing a growing concern about how far into the future learning science research should look to appraise the qualities of learning activities and outcomes. Short-term assessments of learning performances may not be as predictive as we would hope of cross-situational uses of concepts, skills and other achievements in the realism of longer time frames. This concern is clearly related to how outcomes from different settings of learning are and should be portable to other situations, be dependable when the need arises to use them in different situations, and prove sustainable in terms of providing preparation for further learning. Examination of these issues could open additional dialogues about redefining the "transfer of learning" theoretical construct, and related concepts such as "generative learning." In this symposium, based on some cutting-edge research on knowledge integration of learning outcomes from different classes, across formal and informal learning settings, and for longer time periods than usually taken up by learning science research, we would like to propose to define a new set of learning goals as assuring the *portability*, *dependability*, and *sustainability* of learning outcomes.

Naomi Miyake and Roy Pea will open this symposium by proposing a new perspective of long-term, wide-ranged learning, and by proposing a new set of learning goals. While people gain many different learning outcomes from various "learning situations," their integration and maintenance has not been much focused on in research. By taking a closer look at how learning outcomes from different classes at school are naturally integrated (or not integrated) in an individual, we could begin to understand an underspecified aspect of knowledge integration ranging for longer time learning, across many different learning situations. We need to better understand how learning outside of school relates to learning within schools and other designed environments, and how learning in school can spur related learning outside formal designed environments. This new look would reveal not only the complex interaction of formal and informal learning, and their different and sometimes conflicting properties (e.g., locus of control; emergence), but also the lack of supports to enable people to take full advantage of the complexity of these interrelationships.

Brigid Barron will present her newest work on the fascinating nature of middle school learners' developing technological fluencies, across different learning ecologies, and commonly with peers and distributed resources. She will describe a learning ecologies framework and an associated empirical research agenda to deal with how adolescents often pursue learning opportunities both in and outside of school once they become interested in a topic.

Dan Schwartz and Lee Martin will describe a new type of transfer measure, called "Preparation for Future Learning." Ideally, experiences in school can prepare people to learn and adapt once they leave school. They will present several lines of empirical results that show its value for detecting people's readiness to learn and adapt to new situations. They will also hypothesize about ways that the PFL assessments could be extended to help indicate which school-based experiences can prepare people for lifelong adaptation.

Naomi Miyake will report on her team's research on explicitly supporting the college level learning by paying closer attention to the acquisition of the portability, sustainability and dependability of what they have learned, what they are learning, as well as of what they are going to learn after graduation. Her team focuses on the acquisition of 'schematic' knowledge, a form of expertise expected to allow the learners to apply it to solve the wider scope of similar problems, as well as to create new problems and solutions. Her team has been developing and testing college level learning environments in the domain of cognitive science, emphasizing the acquisition of some explicit metacognitive schemata on how people learn, and how they could take advantage of such knowledge. In the two-year course, the students are first introduced to the notion of schematic learning by experiencing their own formation of schemata, and then are guided to reflect upon the process, through carefully designed collaborative activities, supported by technology. They are also constantly encouraged to form a schema from their learning experiences of different classes, as well as to integrate their learning experiences with scientific literature through collaborative discussion. She will describe on the theoretical bases of the practice, concrete learning activities, technological supports, and some results of the evaluative analyses of the learning processes and the outcomes.

Roy Pea will present findings from the Family Math project, involving interviews and observations of 20 diverse families to understand when, how and under which conditions mathematical practices arise in everyday problem solving and interaction. When do daily contexts generate common or distinctive problems that are solved with mathematical concepts and tools (and of what kinds), what resources do family members use for solving problems together, how are activities structured socially, and in what ways does such mathematical activity leverage —but also differ significantly from— knowledge acquired in formal settings? Unlike many school-based mathematical problems, those arising in family life do not come prepackaged with well-defined goals, pre-established problem-solving methods and normative solution paths. As problems emerge, family members must decide whether and how to deal with them. Playing central roles in when and how math-relevant activities are approached and engaged are *interacting value systems* (e.g., time-efficiency, cost-efficiency, different kinds of costs to error, social accommodation to power relations inside and outside of the family, aesthetics, and for some families, the symbolic value placed on 'school math'). The types and dominant family mathematical activities for roughly four hundred reported and observed math events illustrate the complexity of the math that is engaged. The content put to use in families is wide ranging and often more than one type of math is brought to bear, including fractions, decimals and percents; ratios and proportions (direct and indirect); measurement and conversion; probability and odds; basic geometry; charts and graphs; statistics (such as averages), and statistical comparisons.

Rogers Hall, Ken Wright, and Ka:ren Wieckert will report ethnographic and cognitive studies of learning, teaching, and generalizing statistical concepts as statisticians advise clients across different research domains (e.g., the epidemiology of infectious disease, laboratory research on human metabolic processes, the community ecology of social insects, and large-scale conservation planning). By comparing consulting sessions across consultants and client domains, his group seeks a better understanding of how the same concepts (e.g., statistical independence) are made generally applicable in different research contexts. Their approach treats complementary expertise between statistical consultants and their clients as a critical context for cognitive and interactional processes of teaching, learning, and generalizing statistical concepts.

More detailed papers by Barron, Schwartz & Martin, and Hall, Wright & Wiechert follow.

A multiple case study on middle school learners' technological fluencies across different learning ecologies

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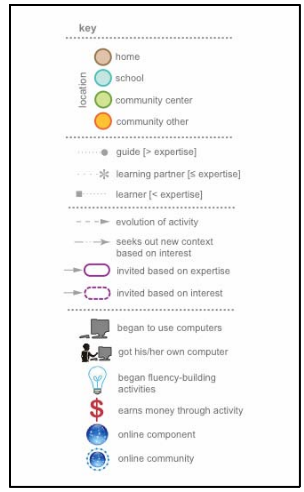
In this presentation I will report a study that was designed to better understand the conditions that support children's persistent engagement in technologically mediated activities that are likely to build knowledge, confidence, and interest in a broad range of subject domains including digital arts, computer science, and human computer interaction. This works builds on ecological and developmental perspectives, and is designed to contribute to a larger research agenda that seeks to better articulate the interdependencies between child level and environmental variables in development and acknowledge the tight intertwining of person and context in producing developmental change (Bronfenbrenner, 1979; Cole, 2000; Lerner, 1991; Lewin, 1951; Rogoff, 2003). One focus within this broad agenda involves further specification of types of roles people play in a learner's knowledge network and how these support learning interactions, description of the nature of activities that propel learning and the ways that activities evolve over time or with age, and the role of distributed resources such a books or Internet based communities (Barron, 2004; 2006, Barron et al, 2007).

In this study eight middle school students, their parents, one of their teachers, and any learning partners they nominated were interviewed. A two-stage process was used to identify these case study participants. First we administered a survey focused on use of computers to approximately 50 students at a public middle school located in the Silicon Valley region who were currently enrolled in either a programming or a web design class. Second we interviewed them about their activities that they sustained after school. Our multi-informant interview methods yield reports on learners' histories in the form of conversations between the interviewers, the learners, and their parents. Responses to questions posed by the interviewer include rich information about children's activities, their learning resources, the ways their parents and peers support their learning, as well as their future goals, attitudes, and interests. These interviews are summarized to create portraits of learning about technology in a genre that has been called "technobiography" in recent work (Henwood, Kennedy, & Miller, 2001). A life narrative approach allows us to chart a learning history in terms that go beyond metrics such as numbers of courses taken to include the meaning and attribution behind decision making and narratives of how the learning activities unfolded across time, resources, and historical context (Bruner, 1994; Elder, 1994; Linde, 1993). In addition, interviews can reveal processes that are missed through other methods and provide us with portraits that go some distance toward "recovering the person" in our theorizing about human development (Mishler, 1996).

Beyond these informant accounts of learning, the interviews offer a sample of language that can be analyzed with respect to vocabulary, means of expression, and syntax. In order to maximize the potential for developing new insights from these records, Barron's research team has created a number of intermediate representations that summarize the raw interview data. Each representation highlights unique information contained within the records. These representations include *narrative texts* that tell a learners' story along a number of set dimensions; *excel spreadsheets* that tabulate types of learning resources and allow us to code and quantify variables such as the number of people in the child's knowledge network or the number of structured learning contexts a child has participated in; *lists* of the technical terms a learner used while recounting their history or describing a project they created during the Artifact Based Interview; *formal codes* for parent roles that are applied to turns; *graphs and tables* that present descriptive statistics for each code; and finally, *visual representations* in the form of developmental timelines that locate fluency building activities across setting and age, depict relations between activities, show the involvement of peers or adults in the activity, and note the types of material resources used for learning. *Developmental timelines*. This visual representation easily lets us see where activities are clustered, when they began, who was involved. Comparing the timelines of individual learners highlights differences in developmental history (see figure 1).

These portraits, as well as our others, have revealed the critical role that parents, peers, and other mentors play in supporting the engagement of these highly engaged learners. The participation of peers or adults in activities was sometimes recruited by the learner, and other times parents or others recruited the child's attention and led the learning. In other cases the forming of a teaching/learning partnership was a highly reciprocal and interdependent process. Though socio-cultural perspectives have emphasized social learning processes generally, and the importance of guided participation specifically (Rogoff, 2003), the variety of roles played by others in our cases is striking and suggests the value of further specifying types and patterns of participation as an important direction for future research. The number and diversity of learning partnerships, their duration, and their content, are all variables that could be productively defined and perhaps quantified. To that end we have begun to develop coding schemes that can help us better specify social learning networks and chart how they differ for individual learners. Parent roles in learning were developed based on a review of the transcripts for the learning ecologies and parent interviews of all eight cases. We believe that they will help account for important individual differences in engagement and conceptual development and have implications for how we seed informal learning networks. In this presentation, individual portraits and the analysis of parent roles in learning will be presented



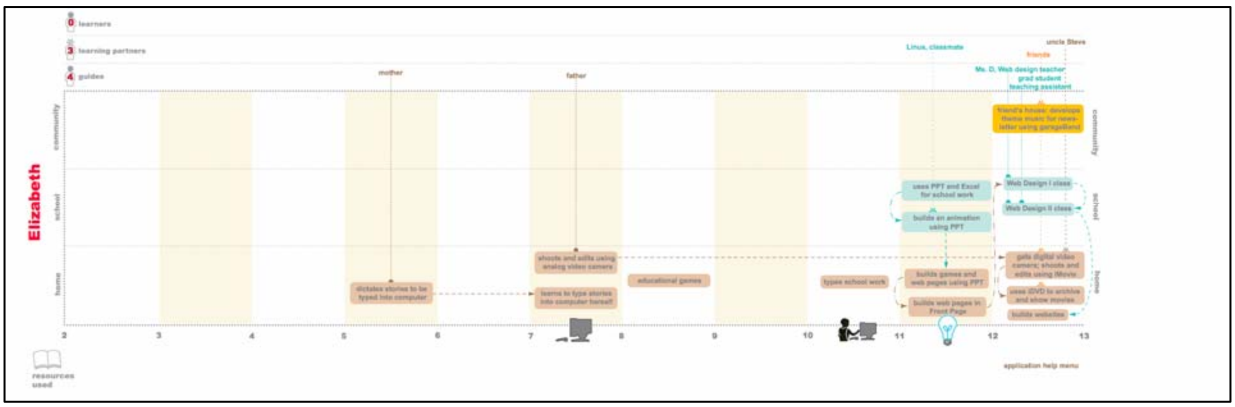


Figure 1A & 1B. Example of a learning history visualization and key

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INSTRUCTION AND ASSESSMENT FOR FUTURE LEARNING

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The learning measures used in many instructional studies are retrospective; they ask what students have learned. However, if one's interest is whether instruction will help people continue to learn once they leave school, then it may be more appropriate to use prospective measures. Over the past few years we have been working on developing and evaluating prospective measures of learning. We first describe the characteristics of retrospective and prospective measures. We then describe how we have used these measures to differentiate instruction that prepares people to learn. These studies have all occurred on a short-time scale within schools. Therefore, we also present the results of a study that examined the long term effects of sustained education on people's preparation to adapt and learn from new situations.

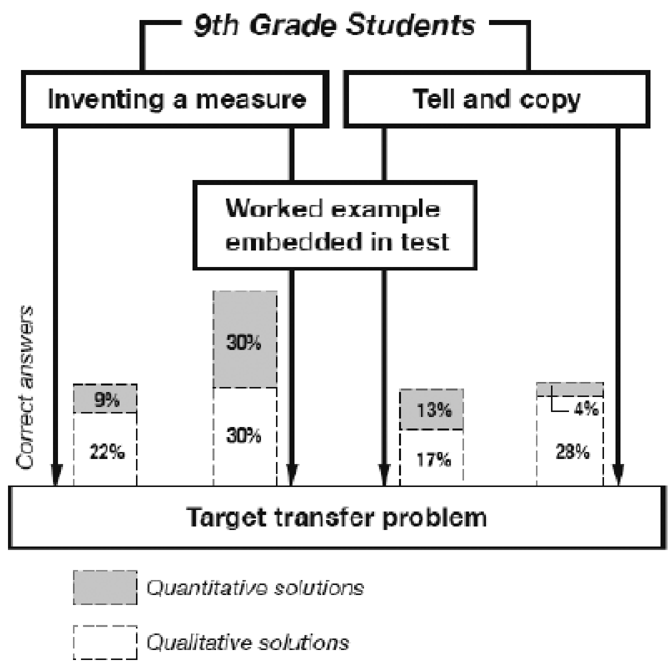
Retrospective measures take a common form called Sequestered Problem Solving (SPS) (Bransford & Schwartz, 1999). Students receive a problem or series of problems, and like a jury, they are sequestered from any resources that might help them learn during the test (and contaminate the results). SPS measures are excellent for determining the efficiency with which students can apply their prior knowledge to solve problems. A limitation of SPS measures is they do not directly measure student abilities to adapt to new situations and learn from them. SPS measures do not include any resources for learning. Students may flexibly use what they know to solve a tricky problem, but they cannot adapt their understanding in response to new information in the environment, because there is no new information.

Prospective measures differ from SPS measures because they include resources for learning at the time of test. These resources can include feedback, verbal materials, examples, and even other people. The question is whether students have been prepared to take advantage of these learning materials to help themselves learn how to solve a novel problem. Such prospective assessments measure students' Preparation for Future Learning (PFL). It is fair to say that PFL assessments are transfer measures, because students need to transfer learning from prior experiences into a novel experience or problem, which differs significantly from problems that they have already solved. Yet PFL assessments are different than most transfer measures; PFL assessments examine whether people can transfer to *adapt* and *learn*, whereas most transfer measures examine whether people can *recognize* that they have already solved a given problem type. The emphasis on learning and adaptation makes PFL measures highly relevant to issues of whether and how school experiences can prepare people to be life-long learners.

Over the past few years, we have been conducting studies that show that PFL measures capture something different from SPS measures when it comes to readiness for future learning (see Schwartz, Bransford, & Sears, 2005 for examples). A primary goal of these studies has been to show that some types of instructional experiences lead to learning gains on PFL measures, even though these instructional experiences may not yield any appreciable differences on SPS measures. This has been useful in showing the hidden value of pedagogies that engage students in creating knowledge rather than only receiving and practicing.

For example, in a study with college students, we compared (a) students who analyzed and looked for patterns in simplified data sets from classic psychology experiments; and (b) students who wrote a summary of a chapter on the same psychology experiments (Schwartz & Bransford, 1998). On an SPS true-false test immediately following these learning experiences, the summarizing students performed much better, presumably because they had read tidy summaries of the studies. However, an additional, PFL measure revealed what the SPS measure could not: the analyzing students were better prepared to learn new material. Students from both conditions heard the same lecture that explained the psychological experiments, their results, and their implications for broader human behavior. To see if the two groups were equally prepared to learn from this shared learning opportunity, we had them predict the results of a novel experiment which was highly relevant to what they had learned, but had very different surface features. On this transfer test, the students who had analyzed the data did much better than the students who had summarized the chapter. It was not simply that data analysis taught them more, because a comparison group who analyzed data but never heard the lecture performed very poorly on the transfer test. Instead, students in the data analysis condition were more prepared to learn from the lecture and then transfer this learning to make predictions about the novel experiment. Had we not included a PFL assessment, the data analysis activity would have seemed like a waste of time, because the students did so poorly on the SPS test relative to students who summarized the chapter. Notably, after the data analysis students had heard the lecture, they did extremely well on the SPS measure. Knowledge-creation opportunities need not look bad by retrospective measures of learning, if those opportunities are complemented by formal treatments that help students organize what they have learned.

As a second example, we describe a study with hundreds of 9th-grade students in which we compared two methods of teaching statistical concepts and procedures associated with variance (Schwartz & Martin, 2005). In one condition, students received standard tell-and-practice lessons. In the second condition, students had to invent their own formulas for solving a set of problems. After attempting to invent their own formulas, the students were shown how experts solve these types of problems. Students in both conditions had the same time on task. After several weeks of instruction, students received a long posttest, which contained a target transfer problem. It was a very far transfer problem, because it included novel content and a novel type of problem (i.e., finding and using standardized scores to compare athletes across history). Because we did not expect many students to be able to solve this problem in SPS form, we included a learning resource within the test. The students received a worked example in the middle of the test showing how to solve a problem, and then they had to copy the steps using a new set of numbers. For these students, following the worked example was quite easy, and nearly all of them did it perfectly on the posttest. The question was whether they would learn from the worked example, which held the key to solving the target transfer problem later in the test. To make sure any differences between conditions were due to learning from the worked example, we constructed two forms of the test. For half of the students in each condition, their test included the worked example. For the other half of the students in each condition, we omitted the worked example. Including the worked example made the transfer problem a PFL measure, and excluding the worked example made the transfer problem an SPS measure. The figure shows the combined results of the original study and a replication study. We coded answers to the transfer problem whether they were correct quantitatively or correct qualitatively (for example, a student made a graph instead of computing). The results showed that the PFL version (that included the worked example to learn from) was more sensitive to the differences between conditions than the SPS version (no worked example in the test). The results also showed that one of the benefits of asking students to create knowledge is that it prepares students to learn subsequently and to spontaneously apply that learning later.



If we extrapolate from the preceding studies, it would appear that a steady diet of tell-and-copy instruction may not prepare students to learn once they leave school. In contrast, opportunities to create knowledge in school may prepare students to learn and create knowledge once they leave school. Of course, this is a speculation. We did find that, a year later, the 9th-grade students in the statistics study showed excellent memory for the statistics they had learned, but we did not test whether they were learning better in their other classes, let alone outside of school.

In more recent work, we have been examining whether sustained school experiences can have a lasting influence in how people adapt and learn from new situations. In one study, we provided participants with a medical diagnosis task. They received a set of reference cases, which included test results and disease diagnoses for several patients. Participants had to diagnose new patients by ordering tests and considering how the results compared to those in the reference cases. One goal of the study was to determine whether people develop representational adaptive expertise – do people learn to make visual representations to help organize complex and novel information? The critical question was whether the participants would make visual representations to help them organize information in the reference cases and thus help them optimize their ordering of tests and diagnoses. To examine the effect of school experiences, we compared undergraduates with graduate students. The graduate students were selected to only include students who worked in data rich fields (e.g., biology, computer science). The undergraduates and graduate students completed the task with the reference cases always available. This made it possible for them to solve the problem without creating a visual representation; they could work by shuffling through the references cases. Both conditions were successful at diagnosing the new cases. However, the results indicated that all of the graduate students created visual representations to help solve the diagnosis problems, whereas very few of the undergraduates made any sort of explicit representation. Creating the visual representations slowed down the graduate students relative to the undergraduates. But, in the long run, creating the visual representations paid off. The graduate students were more optimal in their ordering of tests, and they were able to diagnose the new cases just as quickly. In addition, there was a second phase of the study, where both groups received a new set of reference cases about several new diseases. The graduate students were able to outperform the undergraduates in search optimality and time per diagnosis. It was not the case that undergraduates did not know how to use visual representations. In a third condition, another group of undergraduates completed the same task, but we removed the reference cases each time they received a new patient (they were allowed to consult the reference cases between patients). In this case, the undergraduates did make visual representations to help alleviate the memory burden. All told, the results indicate that extended experiences with managing complex information (i.e., as a graduate student) transferred to a new task. The graduate students spontaneously created visual representations, even though they could have solved the problems without them and the task of creating the representations led to a temporary inefficiency. They were exhibiting adaptive behavior, because they did not just plow into the problems, but rather, they took the time to create some organization that would help them work and learn more effectively in the long run.

In summary, we have been looking at ways of measuring people's abilities to adapt and learn in new situations. This is relevant to life long learning, because in contemporary society people need to adapt to new jobs, technological innovations, and so forth. With the help of these new PFL measures, we have begun to illuminate the experiences that prepare people to continue learning, and we have been able to document the effects of sustained experiences on people's readiness to adapt and learn in a new situation.

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Learning in Activities that Cross Disciplinary Boundaries

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We report ethnographic and cognitive studies of learning, teaching, and generalizing statistical concepts as statisticians advise clients across different research domains (e.g., the epidemiology of infectious disease, laboratory research on human metabolic processes, the community ecology of social insects, and large-scale conservation planning). By comparing consulting sessions across consultants and client domains, we seek a better understanding of how the same concepts (e.g., statistical independence) are made generally applicable in different research contexts. Learning, from this perspective, occurs both at individual and collective levels of analysis, involves not only people but also a dynamically distributed technical culture of things (algorithms, code fragments, graphical displays, and argument structures), and extends in temporal scale from moments to years. This approach treats complementary expertise between statistical consultants and their clients as a critical context for cognitive and interactional processes of teaching, learning, and generalizing statistical concepts. Consultants and clients each know different things, and a successful outcome—a set of findings based on a defensible model for a client's research problem—requires that these differences are turned into complementary strengths in the consulting relation. Field data include audio and video recordings of consulting meetings, semi-structured interviews about material selected from these recordings, historical and ethnographic analysis of changes in client work practice, and working documents produced and used in consulting sessions.

Within consulting meetings, three recurring processes appear to drive learning and teaching, with far-reaching consequences for client work practices and for the career trajectories of participating statisticians.

(1) Consulting narratives (stories) assemble future work. Consulting meetings involve purposeful efforts to displace some aspect of the client's existing infrastructure for representation and modeling with another way of working. In this sense, consultations are a disruption in the client's project timeline, and within the meeting, different ways of assembling the client's future work are created and compared in conversation. These are produced as narrative structures that involve basic processes of animation, gesture, and inscription to assemble new ways of working. Each such narrative assembly orders objects in the client's work (e.g., specimens, machines, and systems of classification), people on the project as human labor and spokespersons for objects, and statistical techniques or concepts.

For example (Hall, Wright & Wieckert, 2007), in a consultation between a biostatistician and entomologists considering the use of cluster analysis (CA) to identify new termite species, a senior research client proposed using CA to *confirm* insect groups they observed in the field. The consulting biostatistician pointed out that CA finds clusters, regardless of their meaning, and a second senior researcher proposed, instead, that they use CA to *discover* insect groups that are confirmed using independent field and laboratory data. This seemingly simple, narrative repair in how CA should be used in the client's work avoided a logical error and, over time, became a standard method for identifying group structures as species candidates.

(2) Parables position clients' statistical decisions. Statisticians (exclusively, in our case studies) tell parables that offer clients alternative subject positions in stories about statistical inference and data modeling. These stories have highly evaluative outcomes, depending on which position a client takes. For example, in the case of entomologists using cluster analysis (above), the statistician compared their situation to blood type shown on a California driver's license. The lead entomologist initially responded from the position of a harried Type O blood donor, but later realized that in the completed parable, he would grant licenses on the basis of blood type (i.e., blood type is a real structure, but it has nothing to do with obtaining a driving license). In another example concerning whether to cut a continuous variable around high/low risk values for diagnostic use, a senior biostatistician told a story in which a doctor following "evidence-based medicine" mis-used a blood cholesterol test:

> I mean I knew an eighty-four-year old woman with leukemia who grew up in New Orleans and loved French cooking, whose doctor told her to quit eating French food, 'cause her cholesterol was high. Um, the doctor should have been shot, or sentenced to McDonald's for a year.

In both examples, subject positions offered to clients (in some cases to other statisticians) are meant as cautions or criticisms, pointing to common mistakes they should avoid when using statistical concepts or techniques.

(3) Analogical reasoning builds project infrastructure. A third and centrally important process of learning and teaching in statistical consulting is the use of analogy to borrow and modify statistical methods or approaches to modeling appearing in prior publications, sometimes out of field for research clients. SCADS findings here are similar Dunbar's (1995) studies of scientific research groups, but in our cases, consulting statisticians work as brokers to map and evaluate analogies that are brought into consulting meetings by research clients.

For example (Hall, Wieckert & Wright, 2006), in a case where research epidemiologists were seeking to estimate the number of young children hospitalized with influenza (these could not be counted completely), the lead researcher borrowed a capture-recapture estimate (CRE) from prior publications in epidemiology, but made an overly narrow assumption about matching hospital days for two screening procedures. The consulting statistician advised that matching days were not required, yet the client was not convinced, posing an extreme case in which a 1 day screen would be incorrectly (he thought) combined with a 7 day screen. After further discussion and a concrete demonstration, the statistician was able to convince the client to use all screening days, and the resulting estimate of children with influenza (now in print) was more robust. In the same consultation, the statistician convinced epidemiologists at a national public health agency that screens with quite different coverage could be combined, as long as there were no dependencies (temporal or otherwise) among them. As a result, new studies and a national influenza monitoring program for adults are underway, using the client's extreme negative case (1 versus 7 screening days) as a *feature* of the new health surveillance system.

Looking across SCADS cases and ongoing analyses, we find a multi-lineal process of learning, teaching and development summarized in Figure 1. Client research projects have ongoing histories (shown as dashed lines) that are intentionally disrupted (Hall, Stevens & Torralba, 2002; Engestrom, Brown, Christopher & Gregory, 1997) in consulting meetings with statisticians. In these meetings (shown as shaded regions) different ways of assembling the client's research and statistical modeling are proposed and compared (i.e., narrative assembly, evaluative use of parables, and analogical reasoning), and new uses of models circulate back into the published literature, where they are borrowed and extended by other investigators. The capacity of client research groups is expanded, and statistical consultants act as "boundary spanners" or brokers (heavy line) by moving across projects and accumulating a consulting portfolio. Within particular research fields these multi-lineal patterns of circulation yield a kind of horizontal development, as clients' research methods and group capacity become more powerful. By moving across different research projects and fields, statisticians find opportunities for vertical development of new and more powerful (or more useful) statistical methods.

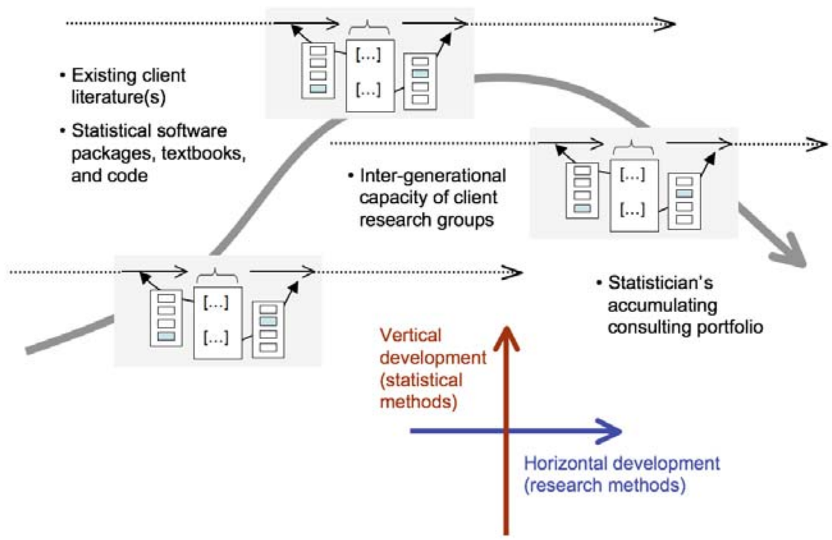

Figure 1. Statistical consulting as an intentional disruption to research clients' work practices. Consulting trajectories help put new and more powerful methods into circulation within research fields (horizontal development), while providing statisticians with opportunities to create new statistical methods (vertical development).

Our analyses and findings support a view of statistical consulting as a set of boundary encounters, places where clients and statisticians bring complementary expertise to bear on particular research problems, craft "do-able problems" (Fujimura, 1987) that enable clients to answer questions in ways that are appropriate and more powerful than they might manage on their own. These boundary encounters occur in organizational environments already dense with resources for modeling, statistical description and inference (i.e., prior publications, statistical software and user-extensible code, consultants with identified expertise, and diverse capacity within research groups). As a result, statistical concepts are used more widely across research projects and fields, this use involves changes in client work practices (including what researchers "know" and the nature of arguments they make), and the statistical concepts, themselves, take on new meanings and potential as research tools. In this sense, statistical consultations feed back into a larger, distributed system of resources for conducting research, a boundary infrastructure that we have analyzed simultaneously at interactional and historical levels.

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Orchestrating learning activities on the social and the cognitive level to foster CSCL

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Abstract: CSCL includes a wide range of scenarios that integrate individual and collaborative learning. Scripts have repeatedly proven useful for guiding learners to engage in specific roles and activities in CSCL environments. The effective mechanisms of scripts in stimulating cognitive and collaborative processes, however, are not yet well understood. Moreover, scripts have been shown to be somewhat inflexible to variations in needs across individual learners, specific groups, and classroom constellations. In this symposium, we present research on how scripts impact socio-cognitive processes. The symposium additionally focuses on how CSCL environments can be orchestrated through flexible scripts that adapt to meet the special requirements at the classroom, small group, and individual levels.

Orchestrating learning activities on the social and the cognitive level to foster CSCL

CSCL covers a range of scenarios in which learners both interact with each other supported by technology and engage in phases of individual learning activities, e.g., computer-mediated learners individually access specific resources before communicating through an asynchronous discussion board with each other (Dillenbourg & Fischer, 2006). But learners seem to rarely draw on CSCL's potential to engage in specific learning activities both on the cognitive and the social level. Hence, CSCL often benefits from socio-cognitive structuring, for example, in the form of scripts that guide learners' interactions (Fischer, Kollar, Mandl, & Haake, 2007). While scripts generally aim to facilitate specific socio-cognitive learning activities, scripts may have different foci and granularities leading researchers to distinguish between macro- and micro-scripts (e.g., Dillenbourg & Jermann, 2007; Kobbe et al., in press). Micro-scripts focus on specific activities of learners and may, for instance, prompt learners to build their arguments in a specific way or instruct students how to collaborate effectively. Macro-scripts rather support the teacher to implement CSCL scenarios within the classroom orchestrating individual and collaborative learning phases (e.g., by suggesting individual preparation before entering discussion). There is some need to better understand how micro- and macro-scripts can be tuned to orchestrate learning activities on the social and the cognitive level to foster CSCL. First, to understand how and when CSCL should encompass collaborative and individual learning activities, the effects of scripts on processes and outcomes of collaborative and individual computer-supported learning need to be investigated. Second, to understand how scripts should orchestrate learning activities on the social and the cognitive level, macro-scripts should be investigated that guide learners through the different individual and collaborative learning activities.

Research Presented

To answer these questions, we present studies ranging from hypotheses testing to design study and investigating micro- and macro-scripts. This symposium first focuses on how scripts can affect cognitive and collaborative processes in integrated learning environments (the studies by Weinberger et al. and Diziol et al.). The Weinberger et al. study indicates that CSCL has additional benefits over individual learning scenarios only when the collaborative learners are supported with a script that facilitates the construction of single arguments. The Diziol et al. study examines the extent to which learners in an individual learning environment that incorporates an intelligent tutoring system benefit from working collaboratively with a script that guides learners through different individual and collaborative phases. These phases include adaptive and meta-cognitive components. The second focus of this symposium is on how scripts can guide learners through different social levels by assigning learners to discussion groups based on differences in perspectives (the studies by Clark & Sampson and Dillenbourg et al.). The Clark & Sampson study compares a script that assigns learners to discussion groups based on their individual positions in comparison to a script that assigns learners to defend a specific perspective. The Dillenbourg et al. study presents a computer tool that supports teachers as they design and adapt a script that assigns learners to discussion groups based on their individual positions (similar to the Clark & Sampson study) to orchestrate learning activities on different social levels.

Scripting argumentative knowledge construction: Effects on individual and collaborative learning

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In argumentative knowledge construction (AKC), learners construct knowledge through the construction of arguments and counterarguments about a complex problem (Andriessen et al., 2003; Weinberger et al., 2006; Weinberger & Fischer, 2006). AKC research thus far has focused on both (1) the individual processes of learners self-explaining the learning material when constructing arguments (Baker, 2003; Stegmann et al., 2006) as well as (2) the inter-individual aspects of AKC involving the added value of confronting learners with peers' diverging conceptualizations of a problem (Leitão, 2000). Research in this area is challenging because social and cognitive processes are highly intertwined. To date, few empirical studies have examined the nature, existence, and added value of the inter-individual aspects of AKC. Exploring differences between individual and collaborative learning is often considered outdated against the assumption that learning in groups exceeds individual domain-specific learning depending on specific conditions that have to be met to foster collaborative learning (Slavin, 1993). Investigating the social form of learning, however, might involve more specific questions on how collaborative learning can be supported to foster domain-specific as well as domain-general knowledge such as argumentative knowledge.

One approach to facilitate AKC in online learning environments involves providing learners with computer-supported scripts that specify, sequence, and assign roles and activities to learners. Scripts may effectively structure different aspects of learners' interactions (e.g., formal or epistemic aspects of argumentation). Some scripts, for example, facilitate argumentative knowledge without reducing domain-specific knowledge acquisition (Stegmann et al., 2006). It remains unclear, however, whether this beneficial script effect is due to a reduction of process losses typically experienced by computer-supported collaborative learners, such as coordination problems (e.g., Strijbos et al., 2004), or the support of meaningful learning activities by the individual learner, such as sound argument construction (e.g., Stegmann et al., 2006).

Research Question 1: To what extent does an argumentative script (with vs. without) and the social form of learning (individual vs. collaborative) affect the formal and the epistemic quality of arguments that learners construct within an online learning environment? Regarding RQ1, we hypothesize that the script would foster the formal and the epistemic quality of arguments of individual and collaborative learners.

Research Question 2: To what extent does an argumentative script (with vs. without) and the social form of learning (individual vs. collaborative) affect individual learning outcomes? Regarding RQ2 we hypothesize that the script would foster learning outcomes of collaborative learners beyond the level that unscripted collaborative and individual learners would attain.

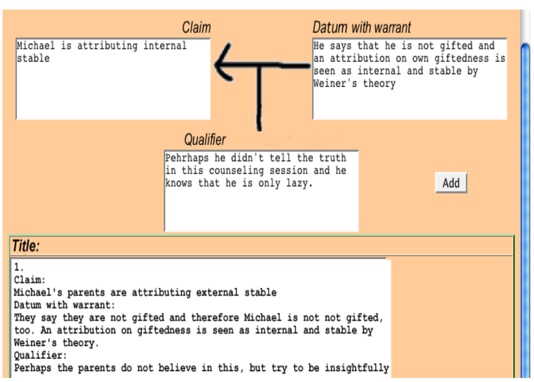
Methods

In this 2×2-factorial design ($n = 72$), we investigate the effects of an argumentative script (with vs. without) and the social form of learning (individual vs. collaborative) on learning processes and outcomes in the context of a computer-supported learning environment in higher education. Learners analyzed problem cases focusing on attribution theory (Weiner, 1985) individually or in groups of three. The script was designed to support specific formal aspects of argumentation, namely the construction of single arguments according to a simplified model of argument construction by Toulmin (1958). The script guides learners to specify their claims, provide at least one datum with a warrant that supports the claim, and identify at least one qualifier of the claim. The script was implemented into an asynchronous CSCL environment involving discussion boards with text windows for each of the three single argument components: (1) claim, (2) datum, and (3) qualifier (see Figure 1).

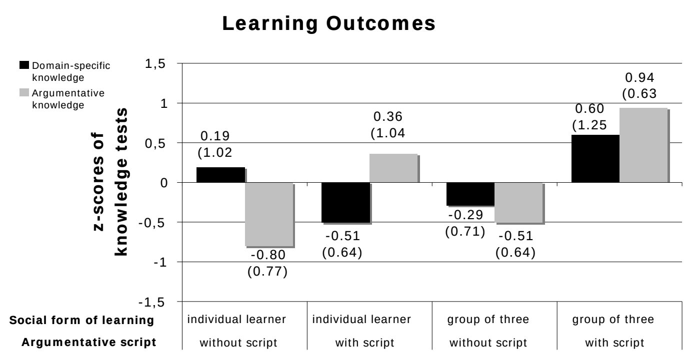
Based on the written analyses of the learners during the online learning session, we analyzed the *formal quality of arguments* (i.e. the frequency of warranted and qualified claims), the *epistemic quality of arguments* within the learning environment (i.e. the frequency of arguments that contributed to solving the learning task by applying specific theoretical concepts adequately to a problem case), individual learning outcomes with a pen and paper test regarding *domain-specific knowledge* (i.e. the extent to which learners were individually able to apply specific theoretical concepts to a transfer problem case after participating in the online learning session), and *argumentative knowledge* (i.e. the extent to which learners were individually able to recall argument components such as claim, warrant, and qualifier and to construct warranted and qualified claims on another topic).

Results

With regard to RQ1, the findings show clearly that the script increases formal quality and reduces epistemic quality of arguments. Although this holds true for both individual and collaborative learners, a positive interaction effect shows that the script particularly facilitates the formal quality of collaborative learners' arguments. Regarding learning outcomes (RQ2), formerly scripted collaborative learners acquired more domain-specific and argumentative knowledge than any other experimental group (see Figure 2). We found a disordinal interaction of the two factors (i.e. script and social form of learning), leading us to compare the effects of each factor controlled by the other factor.



<u>Figure 1</u>. Interface of the scripted discussion board



<u>Figure 2</u>. Z-scores of domain-specific and argumentative knowledge tests: means and standard deviations for each experimental group.

The multivariate ANOVA demonstrates no effects of the social form of learning for learners without support of the script. The multivariate comparisons between learners in groups with script and learners in groups without script ($F(2,15) = 16.26$, $p < .01$; $\eta^2 = 0.68$) as well as with individual learners without script ($F(2,15) = 4.99$, $p < .05$; $\eta^2 = 0.40$) show strong significant effects.

Discussion

(RQ1) The argumentative script facilitates the formal construction of arguments, but has detrimental effects on the epistemic quality of arguments. By focusing learners' efforts to construct formally adequate arguments, the script may have lead learners' attention away from building arguments of high epistemic quality (Dillenbourg, 2002). Learners seemed to somewhat lose sight of the theoretical concepts they were supposed to apply. This may be particularly problematic for scripted individual learners who cannot compensate by drawing on sound arguments from their learning partners (Leitão, 2000). For collaborative learners, on the contrary, the script seemed to reduce process losses normally resulting from learning together online (see Strijbos et al., 2004). (RQ2) Collaborative learning may outperform individual learning regarding learning outcomes when it is structured by a script. Put another way, individuals in unstructured groups did not learn better than individual learners, and CSCL unfolds its potential only, when the degree of freedom is not too large (Kirschner et al., 2006). Scripted collaborative learners acquired more domain-specific and more argumentative knowledge than any other experimental group.

Some limitations of the study should be considered, however. First, earlier studies comparing different supports of AKC for CSCL groups found that argumentative scripts have positive effects on domain-general knowledge but no effects on domain-specific knowledge. Studies with larger samples need to clarify the circumstances and the extent to which argumentative scripts also facilitate domain-specific knowledge. Second, because the participants of the study were first semester students with little prior domain-specific knowledge and little CSCL experience, the findings may not generalize to other, more experienced populations of learners. Future research needs to consider how scripts interact with varying levels of prior knowledge (Kollar et al., 2006). Third, although the problem cases could be regarded as complex (with the possibility of multiple solutions), the problem cases cannot be regarded as genuine group tasks (where co-learners are required to solve the task). Investigating scripts for genuine group tasks may clarify further how scripts need to be adapted to the needs of individual learners and how groups of learners benefit from determining their own procedures (see Clark & Sampson, this symposium).

Promoting Learning in Mathematics: Script Support for Collaborative Problem Solving with the Cognitive Tutor Algebra

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We combined two different instructional methods both of which have been shown to improve students' learning in mathematics: Learning with intelligent tutoring systems (Koedinger et al., 1997) and collaborative problem solving (Berg, 1993). The problem-solving guidance provided by an intelligent tutoring system is effective, but because it places emphasis on learning problem solving skills, a deep understanding of underlying mathematical concepts is not necessarily achieved (Anderson et al., 1995). Collaborative activities can yield elaboration of learning content (Teasley, 1995) and thus increase the potential for the acquisition of deep knowledge, but students are not always able to effectively meet the challenges of a collaborative setting and tap this potential (Rummel & Spada, 2005). Collaboration scripts that prompt fruitful interaction have proven effectively in supporting collaborative learning (Kollar, et al., 2006). We believe that by combining intelligent tutoring and collaborative learning we could foster the advantages of both instructional methods and overcome their disadvantages. Collaborative interaction could augment the effects of an intelligent tutoring system by promoting deeper elaboration, and script support integrated in the tutoring environment could provide guidance to students as they collaborate and thus improve the quality of their collaboration.

Script Design

Our *collaboration script* was designed to guide students in collaborating while solving problems with the Cognitive Tutor Algebra (Koedinger et al., 1997), a tutor for mathematics instruction at the high school level. Its main features are immediate error feedback, the possibility to ask for a hint when encountering impasses, and knowledge tracing, i.e. the Tutor creates and updates a model of the student's knowledge and selects new problems tailored to the student's knowledge level. For the present study we focused on "systems of equations", content novel to the participating students. The script consisted of three components. First, it had a *fixed script component* that structured the problem solving process in two phases. During the *individual problem solving phase*, each student solved a problem in the Cognitive Tutor that consisted of one equation. In the *collaborative phase*, the two students joined on a single computer to solve a more complex system of equations problem that combined the two individual equations. They received instructions from the enhanced Tutor, e.g. prompting them to use collaborative skills. Second, the script had an *adaptive script component* that reacted when students met impasses that resulted in Tutor actions (e.g. hints). To encourage students to take advantage of these learning opportunities, the script asked the dyad to elaborate on the help received. Third, the script had a *metacognitive component.* Following each collaborative phase, students evaluated their collaboration and set goals for how to improve it during the next joint problem solving session. This component aimed at increasing students' ability to collaborate effectively even when no longer receiving script support. This is particularly important due to the risk of overscripting collaboration, i.e. motivation losses yielding reduced performance and learning, a phenomenon that has been discussed in conjunction with scripting for longer periods of time (Rummel & Spada, 2005).

Script Evaluation

We conducted a classroom study with a one-factorial design, comparing scripted collaboration with an unscripted collaboration condition in which students collaborated without support. This study was an initial, small scale study to establish basic effects and to test the procedure in a classroom setting. The study took place during three periods over the course of a week at a vocational high school outside of Pittsburgh in the U.S. Due to the disruptiveness of students in the same class using different interventions, we used a between-class design. The unscripted condition consisted of two classes (12 and 4 students), and the scripted condition consisted of one class (13 students). All classes were taught by the same teacher.

During day 1 and day 2 (*learning phase*), students learned how to solve system of equations problems. Depending on their condition, they collaboratively solved problems either with or without script support. On day 3 (*test phase*) we assessed students' individual and collaborative learning gains with three tests administered within the Cognitive Tutor and a paper and pencil test. The Tutor post-tests assessed the script's effect on students' *problem solving skills*. One post-test asked students to individually solve system of equations isomorphic to those during instruction, thus testing the individual's *retention* of the learned skills. A second post-test asked students to collaboratively solve system of equations without script support to assess the script's effect on improving *collaborative* problem solving skills. Learning from the script should also enable students to capitalize on future collaborations at the Tutor, i.e. it should *accelerate their future collaborative learning*. Hence, the third Cognitive Tutor post-test confronted students with a novel problem type: inequality problems. The paper and pencil post-test concentrated on assessing students' *conceptual knowledge* with two different problem sets. Problem set 1 tested for students' understanding of the *basic concepts y*-intercept and slope: Multiple choice questions asked students to make transformations between verbal, algebraic and graphical representations of those concepts, and open format questions asked them to explain their answers. Problem set 2 assessed students' understanding of the main new *system of equations concept* learned: the intersection point. Again, students had to answer two types of questions: questions with discrete answer possibilities (correct or incorrect), and open format questions that asked for explanations. Scores were summed for each problem set. For answers to the multiple choice questions of problem set 1 (basic concepts), a maximum of 11 points could be reached; the possible maximum for explanations on basic concepts was 22 points. For problem set 2 (intersection point), the maxima were six points for discrete answer format and 12 for open format questions.

Results

The analysis was restricted to students who always worked collaboratively when present, as we are interested in the script's effect on collaborative learning in particular. Due to student absenteeism, only 9 students in the unscripted and 10 students in the scripted condition were included in our analysis. First results of a MANOVA comparing performance of conditions in the paper and pencil post-test showed significant differences between conditions (Pillai-Spur, $F(4, 14) = 7.35$, $p < .05$). Means and standard deviations of the ANOVAs for each variable are displayed in Table 1. Answers to the multiple choice questions on basic concepts did not show a significant difference, $F(1,17) = 2.26$, *ns*. However, the scripted condition outperformed the unscripted condition on the discrete answer questions about the system's concept, $F(1,17) = 22.16$, $p < .01$. Significant differences between conditions was also found for the open format questions of both problem sets with $F(1,17) = 5.85$, $p < .05$ for the basic concepts and $F(1,17) = 17.01$, $p < .01$ for the system's concept.

Table 1: Means and standard deviations of the paper and pencil post-test, assessing conceptual understanding

	Unscripted condition		Scripted condition	
	M	SD	M	SD
Basic concepts: multiple choice	4.89	1.83	3.60	1.90
Basic concepts: open format	.22	.44	1.20	1.14
System concept: discrete answers	.89	1.45	4.50	1.84
System concept: open format	.44	1.33	5.70	3.59

Discussion and Outlook

The script had a significant effect on the acquisition of the main new concept of the system of equations unit, the intersection point. Particularly interesting are the substantial differences that were found for the open format questions of both problem sets, demonstrating a strong effect of the script on students' conceptual knowledge: After scripted interaction during the learning phase, students were better at articulating their mathematical thinking compared to their unscripted counterparts. It should be noted, however, that students in both conditions had difficulties providing explanations and only reached low scores in the open format questions. The amount of wrong explanations and the number of students who did not even try to articulate their thinking was very high. Thus, it might be promising to extend the learning phase in future studies to increase the script's effect. It remains to be seen if the script's effect can also be found in the Cognitive Tutor tests. Currently, we are analyzing the Tutor log files for variables such as number of errors per problem, time per problem, decrease of error rates over the course of several problems etc. Contrasting this post-test data with corresponding data from the learning phase will inform us on differences in students' learning progress. Results of the Tutor post-tests will be presented at the conference.

Fostering Productive Argumentation in Online Environments: Strategies for Grouping Students in Discussion Forums

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Our ongoing research (Clark & Sampson, 2006, 2007) focuses on fostering productive argumentation in science classrooms through a process that involves (a) providing students with empirical data and scientific ideas about a phenomenon, (b) scaffolding students in the creation of an explanation that articulates their ideas clearly and focuses on the salient issues, (c) organizing discussions around alternative perspectives, and (d) facilitating equitable and productive discourse among the students. This study examines the tradeoffs between organizing debates around students' own proposed explanations versus assigning students to conceptually optimized pre-selected explanations.

Our work adopts a view of argumentation as a process where "different perspectives are being examined and the purpose is to reach agreement on acceptable claims or courses of action" (Driver et al., 2000, p. 291). Hence, our efforts to support and promote argumentation in science classrooms have focused on the development of a CSCL environment where students generate competing explanations for a given phenomenon and then examine, discuss, and evaluate these explanations based on available evidence. We have developed *personally-seeded discussions* to support students in this discourse. These customized asynchronous discussion forums (a) scaffold students as they synthesize an explanation to describe data that they have collected, (b) organize discussion groups of students who have created different explanations, and (c) encourage students to critique each other's explanations and work toward consensus based on evidence available to them. Research that we have conducted over the last four years indicates that personally-seeded discussions are an effective way to foster equitable and productive argumentation between students; which we define in this context as a discussion that incorporates the voices of all students, exposes students to new ideas, and creates a need for students to evaluate the legitimacy of alternative viewpoints (Clark & Sampson, 2007).

As discussed above, the current study investigates the tradeoffs between organizing debates around students' own proposed explanations versus assigning students to defend conceptually optimized pre-selected explanations. In particular, we investigate and compare the impacts on student argumentation of two different strategies for organizing and scripting discussions around alternative perspectives. In both interventions, students first create their own explanations to explain the phenomenon under investigation. The software then uses these proposed explanations to automatically sort students into discussion forums with students who have proposed different explanations (and are therefore likely to have different perspectives on the phenomenon). The treatment groups differ in terms of what happens after this sorting process.

> *Personalized Explanations Treatment*: In the personalized treatment group, the students' proposed explanations from the sorting step become the seed comments for the discussion. Because students are sorted into groups with students who proposed different explanations for the phenomenon, some range of explanations is represented, but that range is not necessarily controlled or optimized.

> *Range of Explanations Treatment:* In the range intervention, students are sorted into groups using the same procedures, but the seed comments for the discussion come from a predetermined list of sample explanations generated specifically to represent a range of the critical student misconceptions identified through earlier research. In this approach, students are automatically assigned to defend one of these specific explanations.

In both treatments, students are instructed to critique all of the explanations. Students are further instructed to reply to the comments addressed to them and to focus on evidence. Students are asked to compare their explanations, take into account all of the arguments and evidence, and revise their final answers accordingly. The goal of this scripting strategy is to encourage students to view explanations as objects of cognition (Kuhn, 1993) that need to be critiqued and revised before they can be accepted. In sum, the personalized strategy focuses on engaging students own ideas (while potentially not presenting as optimal a range of explanations to spark discussion) and the range strategy presents an optimal range of explanations from a conceptual perspective but omits the personalization of the discussion (i.e., the students are discussing generic explanations rather than one another's explanations as the seed comments).

Data and Results

To evaluate the relative impacts of the range and personalized strategies, we have been (and continue to) randomly assign students within classrooms to one of the two conditions within a standard WISE project investigating thermodynamics (*Thermodynamics: Probing Your Surroundings*, http://wise.berkeley.edu). In this project students investigate the concepts of thermal equilibrium, thermal conductivity, and the difference between heat and temperature by collecting real-time data and interacting with simulations (see Figure 3) before they participate in the online asynchronous discussion forum. Data is logged on our servers as teachers naturally come to the WISE website and run the project with their students.

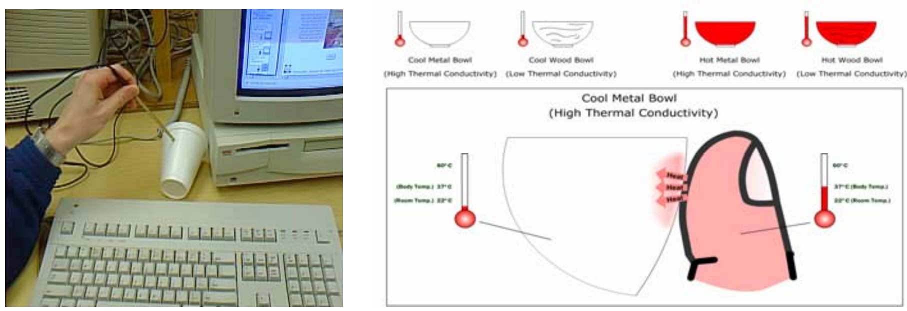

Figure 3. During the online project, *Thermodynamics: Probing Your Surroundings*, students collect real time data (left) and interact with simulations (right) to learn about the thermodynamics.

In this study, as discussed above, students in each class are sorted into discussion groups by the software so that a range of different perspectives is represented in each group. At this point, the software randomly divides the groups within each classroom between the two conditions. This approach allows us to collect data from a variety of classrooms and schools without the intrusiveness of a formal intervention and provides a window into the overall effectiveness of the two treatment groups in an authentic context. Also importantly, this approach maintains the methodological advantages of random assignment *within* classroom rather than *by* classroom.

The data collected by the servers includes: (1) the initial explanations that students submit, (2) full transcripts of the discussions, and (3) the final explanations that students submit after leaving the discussions. We therefore have a pre/post measure of students' proposed explanations as well as the actual discussion transcripts. The initial data suggests that (1) students engage in higher amounts of discourse in the personalized condition as measured by the number of comments made and the average length of comments and (2) students are more likely to select the normatively "correct" explanation subsequent to the discussion in the personalized condition.

These initial findings suggest that organizing discussions around students' own proposed explanations is more valuable than organizing discussions around optimized sets of candidate explanations even though the latter approach guarantees a more thorough presentation of key ideas. These findings further suggest the relative importance of student ownership and motivation in argumentation environments in comparison to the careful orchestration of the conceptual components within the argumentation environment. The full presentation of our data will outline the details of these relationships and their implications for the design of learning environments at the interface between technological and social supports.

The Teacher's Side of CSCL Scripts

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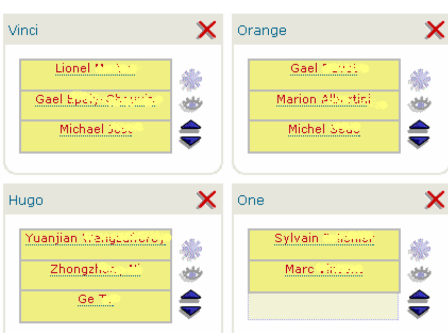
Integrated learning scripts (Dillenbourg & Jermann, 2007) do no only include group activities but also integrate individual activities and class-wide activities. These activities occur in the classroom space and are orchestrated by the teacher. This contribution addresses the general issue of the teacher's role in CSCL activities in a concrete case: how the ManyScripts environment enables teachers to design a script, prepare a session and orchestrate the activities in real time.

Preparing a script instance

This works stems from our European research team (1) on formalizing CSCL Scripts. Most macro-scripts can be described from a small set of elements: a script is a sequence of phases, groups are structured with roles associated to different resources and modes of interactions. The script description scheme (2) would support a top-down approach to script authoring, focusing on a language able to model a large variety of scripts, as it was developed by the COLLAGE group in Valladolid or by the COLLIDE group in Duisburg (3). This approach raises the various difficulties that authoring tools encountered over the previous decades: the tool is powerful but it is not easy for a teacher to come up with an innovative scenario that can be expressed within such a constrained language. Instead, we implemented a bottom-up approach, in which teachers start from an existing script, modify some parameters and edit the content. The philosophy behind this is that the authoring tool is not pedagogically neutral but conveys instead a specific pedagogical model.

Currently, the environment, called ManyScripts, supports editing the script called 'ConceptGrid'. This script is a sub-class of the class of script referred for many years as "JIGSAWS". The 'ConceptGrid' unfolds as follows: 1) Groups of students have to distribute roles among themselves. Roles correspond to theoretical approaches of the domain under study. In order to learn how to play their roles, students have to read n papers that describe the theory underlying their role. 2) Each group receives a list of concepts to be defined and distributes these concepts among its members. Students write a 5 lines definition of the concepts that were allocated to them. 3) Groups have to assemble these concepts into a grid and to define the relationship between two concepts that are neighbours on the grid. The key task is to write 5 lines that relate or discriminate two juxtaposed concepts: if Concept-A has been defined by Student-A and Concept-B by Student-B, writing the Concept-A/Concept-B link requires Student-A to explain Concept-A to Student-B and vice versa. 4) During the debriefing session, the teacher compares the grid produced by different groups and asks them to justify divergences. To use a ConceptGrid script in her course, the teacher has to decide about the group size (number of roles) and edit the contents of the script: she defines the roles, the papers to be read for each role and the sets of concepts to be defined and assembled in a grid by the student groups. The result is what we refer to as a script instance, e.g. "ConceptGridBiology2.1".



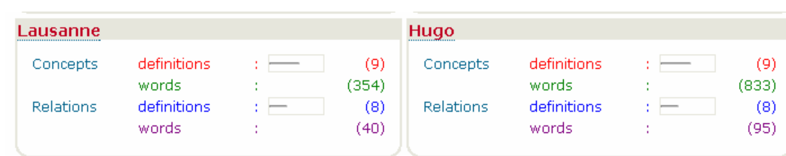


Figure 4b (above). Global look at group work

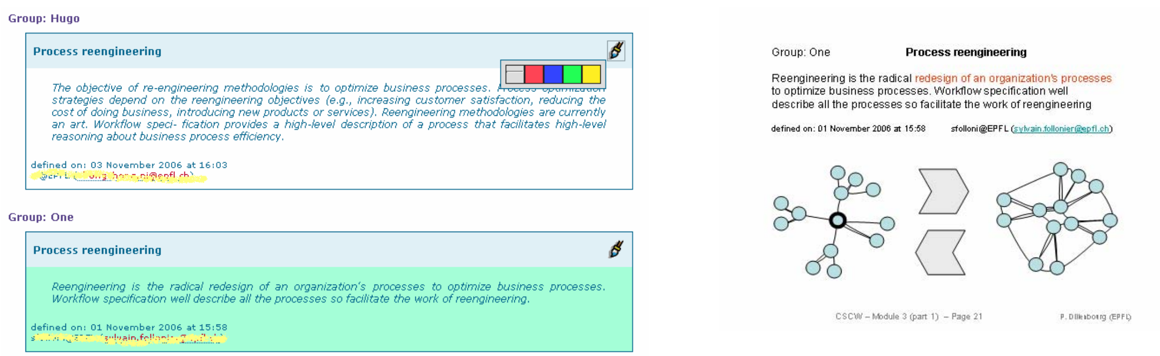
Figure 4a (left). Coping with irregular groups

Preparing a script session

The same script instance may be run several times, for instance if "ConceptGridBiology2.1" is used in two different classes, respectively in winter and summer terms. Hence, the teacher has to prepare two sessions of the script instance, the "ConceptGridBiology2.1.oct06" and "ConceptGridBiology2.1.march07". Setting up a session may sound trivial: the teacher has to provide student names, form groups (or let them do it) and set up the start/end dates for each script phase. This simplicity does not match what happens in actual university classes: some students joint the course late, some drop out, … A common bit tricky problem is when the number of students is not a multiple of the group size. What does the teacher do if 11 students have to be distributed into groups of 2? The ManyScripts environment offers two 'flexibility' options: to handle extraneous group members (groups of 3,4,4) or to handle missing members (groups of 3,3,3,2) as in figure 4a. The system copes with these situations as follows. A team with a missing member/role X may reuse definitions produces by the role-X members of any other team in the class and session. If a team has an additional group member, he or she plays the role of a 'joker' allowed to off-load the work of any other group member; the team is free to decide how to share the workload.

Orchestrating a session

When the script is running, the teacher has the possibility to change some parameters such as the group composition or deadlines up to a certain level. The ManyScripts environment enables the teacher to follow the evolution of teamwork at a high level of aggregation as in figure 4b. More importantly, the 'teacher cockpit' enables the teacher to explore the contents produced by group along different axis: per construct concepts grids, per group, per concept or per relation between concepts. Teachers may use the cockpit for grading the groups' work and, more importantly, for preparing the debriefing phase, i.e. when the teacher discusses the group productions with the whole class. The debriefing can be prepared in different ways. The teacher may annotate with her own colour codes the different productions (Figure 5a). Hence, when she uses the cockpit during the debriefing lecture, she may easily find the definitions she wants to refer to in her comments. Alternatively, she may simply integrate the student productions within her presentations as in figure 5b.



Figures 5a and 5b. Teacher reusing group productions by annotating them within the ManyScripts environment (left) or by integrating them into her lecture presentation material (right).

Experiments

This new release of the ConceptGrid is now being used in an EPFL course, through 4 successive iterations. It is also used in a course for educational management at the University of St. Gallen. The different sessions will be evaluated and compared using content analysis. In addition, a questionnaire will be used to capture students' reactions, and the teachers using the grid will be interviewed. Results will be reported at the conference.

Concluding Remarks

The research presented in this symposium differs to a large extend in terms of addressing micro- and macro-scripts and in terms of presenting hypotheses testing as well as design studies. As a whole, however, the symposium provides a guideline of how to implement (scripted) CSCL in the classroom, how to orchestrate individual and collaborative learning activities, and what effects on learning processes and outcomes to expect of it. Overall, the presented research shows that CSCL may neither unfold its full potential when no structure is provided to the individual and collaborative learning processes (see Fischer et al., 2007) nor when learners are confronted with too much, badly timed or the wrong kind of “support” (see Dillenbourg, 2002). A major focus of future script research therefore is to introduce flexible scripts that can be adapted and modified by both, teachers and learners.

Endnotes

(1) The European Research Team COSSICLE (http://www.iwm-kmrc.de/cossicle/fr_index.html?news)
(2) http://www.iwm-kmrc.de/cossicle/resources/D29-02-01-F.pdf
(3) http://www.collide.info/

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Mice, Minds, and Society

Papers

Classroom Model, Model Classroom: Computer-Supported Methodology for Investigating Collaborative-Learning Pedagogy

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Abstract: We have been exploring the potential of agent-based modeling methodology for social-science research and, specifically, for illuminating theoretical complementarities of cognitive and socio-constructivist conceptualizations of learning (e.g., Abrahamson & Wilensky, 2005a). The current study advances our research by applying our methodology to pedagogy research: we investigate individual and social factors underlying outcomes of implementing collaborative-inquiry classroom practice. Using *bifocal modeling* (Blikstein & Wilensky, 2006a), we juxtapose agent-based simulations of collaborative problem solving with real-classroom data of students' collaboration in a demographically diverse middle-school mathematics classroom (Abrahamson & Wilensky, 2005b). We validate the computer model by comparing outcomes from running the simulation with outcomes of the real intervention. Findings are that collaboration pedagogy emphasizing group performance may forsake individual learning, because stable division-of-labor patterns emerge due to utilitarian preference of short-term production over long-term learning (Axelrod, 1997). The study may inform professional development and pedagogical policy (see interactive applet: http://ccl.northwestern.edu/research/conferences/CSCL2007/CSCL2007.html).

Background and Objective

We present a new methodology for developing and critiquing education theory, *agent-based modeling*. Agent-based modeling (hence ABM) has been increasingly used by natural scientists to study a wide range of phenomena such as the interactions of species in an ecosystem, the interactions of molecules in a chemical reaction, the percolation of oil through a substrate, and the food-gathering behavior of insects (e.g., Bonabeau, Dorigo, & Théraulaz. 1999; Wilensky & Reisman, 1998, 2006). Such phenomena, in which the elements within the system (molecules, or ants) have multiple behaviors and a large number of interaction patterns, have been termed *complex* and are collectively studied in a relatively young interdisciplinary field called *complex systems* or *complexity studies* (e.g., Holland, 1995). Typical of complex phenomena is that they lend themselves to two or more layers of description—e.g., collisions of particles in a gas chamber are the "micro" events, and pressure is the "macro" event— and the cumulative ('aggregate') patterns or behaviors at the macro level are not premeditated or directly actuated by any of the "lower-level" micro elements. For example, flocking birds do not intend to construct an arrow-shaped structure. Rather, each element ("agent") follows its "local" rules, and the overall pattern arises as epiphenomenal to these multiple local behaviors—the overall pattern *emerges*.

Specialized computer-based environments (Collier & Sallach, 2001; Langton & Burkhardt, 1997; Wilensky, 1999) have been developed as research tools for investigating complex phenomena (North et al., 2002; Wilensky, 2001; Wilensky & Reisman, 2006). The agents can be instantiated in the form of a computer program that specifies their rule-based behaviors. ABM is thus particularly powerful for studying complex phenomena, because once the modeler assigns agents their local rules, the modeler can set these virtual agents into motion and watch for any overall patterns that arise from the agents' interactions. E.g., the modeler might assign a group of virtual birds a set of rules and then watch their interactions to see whether typical flock structures emerge (Reynolds, 1987).

Whereas initially complex-systems methods and perspectives arose from the natural sciences, complexity, emergence, and micro- and macro levels of description of phenomena are all highly relevant to research in the *social* sciences. Indeed, the recent decades have seen a surge in social-science studies employing ABM (Axelrod, 1997; Diermeier, 2000; Epstein & Axtell, 1996). *Learning, too, we argue, can be construed as a complex phenomenon, and thus ABM is a potentially powerful research tool conducive to the investigation of patterns, including structures and rules, underlying the emergence of learning*. Specifically, we are proposing to use ABM in investigating the social dynamics underlying participation patterns observed when students interact around collaborative classroom assignments, such as construction projects. Thus, whereas our paper deals squarely with 'mice, minds, and societies'—the theme of the CSCL 2007 conference—we are not so much dealing with computer-supported collaborative learning as such, as much as with computer-supported *inquiry into* collaborative learning (CSiiCL). Nevertheless, we hope to lay out agenda and methodology to facilitate synergies between the CSCL and complexity-studies communities—synergies that increase understanding, within education research, of mechanisms and practice pertaining to individual learning within social contexts. Thus, armed with computers as methodological tools for ultimately improving collaborative learning, this paper *is* about computer-supported collaborative learning.

We have been working with the *NetLogo* (Wilensky, 1999) multi-agent modeling-and-simulation environment. A vision of the NetLogo development effort is that building simulations will become common practice of natural/social-sciences scholars investigating complex phenomena: the scholars themselves—not hired programmers—build, run, and interpret the simulations (Tisue & Wilensky, 2004; Wilensky, 2003). The new lenses of ABM, we believe, will enable education researchers to explore, articulate, develop, and share an intuition we have struggled to study rigorously and express coherently: the intuition that individuals and communities are interdependent through myriad dynamic reciprocities (Cole & Wertsch, 1996; Greeno, 1998).

In the remaining sections of this paper, we: (1) introduce the case study—a collaborative construction project in a demographically diverse middle-school mathematics classroom studying combinatorial analysis (Abrahamson, Janusz, & Wilensky, 2006; Abrahamson & Wilensky, 2005b); (2) discuss the rationale, design, and implementation of a complexity-based analysis of the case-study's participation patterns, i.e., an agent-based model that purports to simulate this phenomenon; (3) introduce 'bifocal modeling' (Blikstein, Abrahamson, & Wilensky, 2006), a computer-assisted research technique for juxtaposing real and simulated data toward calibrating the simulation such that it emulates the real data—we demonstrate this juxtaposition by aligning participation patterns in our classroom data with simulated patterns emerging in the ABM; (4) report findings; and (5) offer concluding remarks on the implications of this study and the limitations of ABM and suggest directions for further research.

Case Study: Emergence of a Stratified Learning Zone in a Collaborative Project in a Demographically Diverse Mathematics Classroom

Complexity-studies methodology is particularly suitable for understanding student learning in pedagogical frameworks that support individual agency. When such classrooms engage in collaborative construction projects, participation patterns emerge, some that may be undesirable, from the educator's perspective. As we explain, below, these patterns emerge through iterative student-to-student negotiation of roles vis-à-vis students' skills and their interpretation of the overall classroom objectives. When these objectives are taken to be *production* rather than *learning*, inequitable participation patterns may emerge, because students are rewarded for their contribution to production rather than for their learning. The interactions of these two reward systems (the first, indexing students' contribution toward successful completion of a group project; the second, indexing students' own learning) is a complex system—ABM enables us to study the nature of students' iterative negotiations that give rise to the inequitable participation patterns. Thus, simulating participation patterns could provide designers and teachers valuable tools for running equitable classrooms. In particular, understanding the emergence of inequitable participation may help educators formulate responses that temper production to the benefit of learning. We now explain the case study that we investigated using ABM.

The Combinations tower: A Combinatorial-Analysis Collaborative Project

The current investigation uses data from a design-based research study of middle-school students' mathematical cognition pertaining to the topic of combinatorial analysis (Abrahamson, Janusz, & Wilensky, 2006; Abrahamson & Wilensky, 2005a). Central to the study was an implementation of a challenging classroom collaborative project—the construction of the *combinations tower*, the exhaustive sample space of a 3-by-3 grid of nine squares that can each be either green or blue (for a total of 512 distinct "9-blocks"). The classroom, working in groups, created all the 9-blocks and assembled them into a very tall "histogram." This histogram consisted of 10 columns running from "no-green" through "9-green" (the columns' heights were, respectively, 1, 9, 36, 84, 126, 126, 84, 36, 9, 1—coefficients in the binomial function $[a + b]^9$).

The Stratified Learning Zone: Group Dynamics From an Emergence Perspective

Data analysis revealed unanticipated participation patterns. Namely, individual students operating within groups assumed by-and-large restricted roles that we named: (a) "number crunchers"; (b) designers; (c) producers; (d) implementers; (e) checkers; and (f) assemblers; and in addition, some students operated between groups as (g) ambassadors. We demonstrated the descending mathematical challenge of the *a*-through-*f* roles, e.g., the designers initiate combinatorial-analysis strategies, the implementers carry out these strategies, and the assemblers glue the 9-blocks onto a poster. We demonstrated that students' individual roles were related both to their mathematical achievement, as reported by the teacher, and their demographics. We argued that these roles were emergent and that they affected the students' learning opportunities and self image and that therefore it is important to understand how some students landed up on the lower rungs of the production line—how a stratified learning zone emerged.

A *stratified learning zone* is a design-engendered hierarchy of students' potential learning trajectories along problem-solving skill sets, each delimited in its conceptual scope, and all simultaneously occurring within a classroom. In comparison, the term *continuous learning zone* depicts a space wherein students can each embark from a core problem, sustain engagement in working on this problem, and build a set of skills wherein each accomplishment suggests, contextualizes, and supports the exploration and learning of the successive skill, so that a solution path is learned as a meaningful continuum.

Validation Through Feedback From the Students and Teacher

Based on interviews with the teacher and the students, we formulated the following agent-based explanation of the emergence of student task distribution. Students' roles emerged as a function of individual student interactions: Within a group, once a student realized that he had reached his limit in terms of mathematical problem solving as compared to another student within that group, the first student would often capitulate to his group-mate the task of pursuing that mathematical problem, and then she would take over, relegating to him a necessary task that was within his zone of achievement, thus freeing herself to focus on the problem he had abandoned. A network of symbiotic relationships crystallized as the more advanced students assumed leadership of their groups and as the emergent task specifications were articulated in terms of student roles and student-to-student and group-to-group negotiated partnerships. The likelihood of an individual student dominating another was affected by personality traits: of the mathematically advanced students, those who were less socially fluent preferred to work individually, whereas "bossier" students were more likely to assign tasks to other group members.

Exploration Vs. Exploitation: A Perennial Tradeoff of Collaborative Inquiry?

When a classroom that is engaged in collaborative project-based activity progresses towards successful completion of the project, could there be any justification to tamper with this progress? And yet, is a facilitator ethically permitted to sacrifice individual students' learning so as ensure the completion of the project? To address this design-and-facilitation dilemma, we will now turn to a complexity-studies perspective on organizations. One could arguably model the study classroom as an organization, a collective of individuals with some shared objective and a modus operandi for working towards this objective. There are no monetary stakes involved, but certain roles enable some students to gain knowledge capital, whereas other roles do not. Our motivation to model the classroom as an organization is that construction projects may tacitly import to the learning space ethics, ethos, and praxis of working spaces that may not be entirely beneficial for all students.

Axelrod and M. D. Cohen (1999) discuss *exploration versus exploitation*, a tradeoff inherent in *complex adaptive systems*, such as organizations. For instance, in allocating resources, an organization must determine which strategy will maximize its benefits—"mutating" to check for better fits with the changing environment or stagnating and cashing in on a proven model of success. Typically, "the testing of new types comes at some expense to realizing benefits of those already available" (Axelrod & M. D. Cohen, 1999, p. 44). We submit that a classroom can be seen as a complex adaptive system (Hurford, 2004), at least in terms of students' within-group free-range agency in problem solving and the interactions that shape these agencies. Initially, all students are explorative. Yet, once a functioning coordination scheme has evolved that is apparently well adapted to the environment, i.e. the classroom-as-a-whole is apparently progressing along a trajectory towards successfully completing a prescribed task and positive sanctioning is received from the forces that be (the facilitators), an implicit quietus is set on any further exploration, and the group achieves dynamic stability. From that point on, the individual cogs in the production mechanism hone their skills and produce (see Durkheim, 1947, for a social critique of the division of labor).

Finding: Some Answers, New Questions

When students are given the freedom to explore a problem collaboratively, both remarkable and undesirable group behaviors may emerge. It is not a zero-sum game—these "pros and woes" need not cancel each other out. An experienced and able teacher who anticipates this emergence and is sensitive to unforeseen behavior can steer this sensitive dependence so as to optimize student sharing and learning opportunities. The proposed methodology introduced in this paper may provide education researchers, designers, and practitioners tools for understanding classroom dynamics such that they can identify points of leverage for working *with* students' natural behavioral inclinations to achieve equitable participation. The next section explores this possibility.

Implementing a Theoretical Model of the Case-Study Emergent Classroom Participation Pattern in the Form of "Runnable" Agent-Based Procedures

In this section, we demonstrate the applicability of ABM methodology for the investigation of pedagogical practice by explaining our design rationale for simulating the emergence of a stratified learning zone in a virtual classroom. Also, we demonstrate the iterative nature of this methodology by describing some of our key understandings, along the modeling process, that informed the improvement of the model. Whereas this paper is primarily *methodological*—we use particular research content so as to demonstrate an investigation technique—the reader may disagree with our *theoretical* model of the causes of stratification. We welcome such disagreement, because we regard it as manifesting a strength of the ABM methodology: scholars from across the disciplines, who may not share literature, constructs, or methodologies, can nevertheless critique each other's work pointedly—ABM is an interdisciplinary *lingua franca* (Abrahamson & Wilensky, 2005a). In fact, readers are welcome to download the model file and modify or replace the procedures so as to express their own hypotheses.

Rationale of the Stratified Learning Zone model: Selection of Key Parameters, Hypothesizing Behavior Rules, and Authoring the Rules Within the NetLogo Environment

Any model, regardless of the medium in which it is expressed, e.g., text, diagram, or agent-based model, is per force an attenuation of the "objective" reality. Initially, the modeler must use circumspection in answering the question, "What is the nature of the phenomenon we are attempting to model?" For example, we asked ourselves whether we are modeling: (a) a specific activity, i.e., "students collaborating on constructing the sample space of the binomial stochastic generator that has 9 variables each with the values "green" and "blue" that are glued onto purple construction paper"; or (b) "students collaborating on a task that demands a variety of roles that range by the content knowledge they foster." We chose the latter option. Next, in building an agent-based model, one defines the agents (e.g., students, teacher) and any other objects at play (e.g., portable artifacts), and assigns the agents properties evaluated as relevant to the phenomenon under investigation, including constants (e.g., gender) and variables (e.g., role in collaborative activity). The modeler's selection of these agents and properties is informed by a general rationale of the model, which the modeler articulates, e.g.:

- Classroom objectives are mandated by a curriculum
- A total of *n* individual students cluster in *m* groups of variable size; whom they group with is a mixture of student and teacher choice (teachers may opt to create either homogeneous or heterogeneous groups)
- Individuals are reinforced by their group-mates for contributing toward a group's objective, where 'contribution' is measured vis-à-vis the project specifications

For the stratified learning zone (SLZ) model, we chose a puzzle task (see Figure 1, below). This linear puzzle consists of set of pieces that need to be concatenated according to a logical sequence. Necessary activities within this task are retrieving pieces (simplest task), connecting pieces (most demanding task), and verifying (intermediate demand). Thus, the roles that students might specialize in are piece-retrievers, piece-connectors, and puzzle-verifiers. Puzzle pieces are scattered all over the classroom. Retrievers wander around and, when they find a piece that they evaluate as useful (it may in fact be incorrect), they go back to their group's table, deliver the piece to the connector and then return to retrieve more puzzle pieces. Upon receiving a piece, the piece-connector evaluates its fit to the puzzle in its current state. If the piece is not suitable, the piece-connector orders the piece-retriever to drop the piece somewhere else and bring a new one. If the piece is suitable, the piece-connector takes it and tries to add it to the puzzle. Once the puzzle is completed, the puzzle-verifiers check it. If one piece is out of place, the group has to re-assemble parts of the puzzle. For each task, students increase their skill (faster and/or more accurate). Overall group performance is evaluated by the correctness of the puzzles and time-to-completion. Our independent variables are: (a) pedagogical style (with or without mandated role rotation); (b) students' initial skill level for each task and distribution of skill levels within student; and (c) task difficulty. Note: As a measure of achieving initial "reliability"—evaluating whether the model rationale indeed expresses what it purports to express—the modelers first worked individually and only then shared notes. We could thus partially validate our conjectures through inter-modeler triangulation.

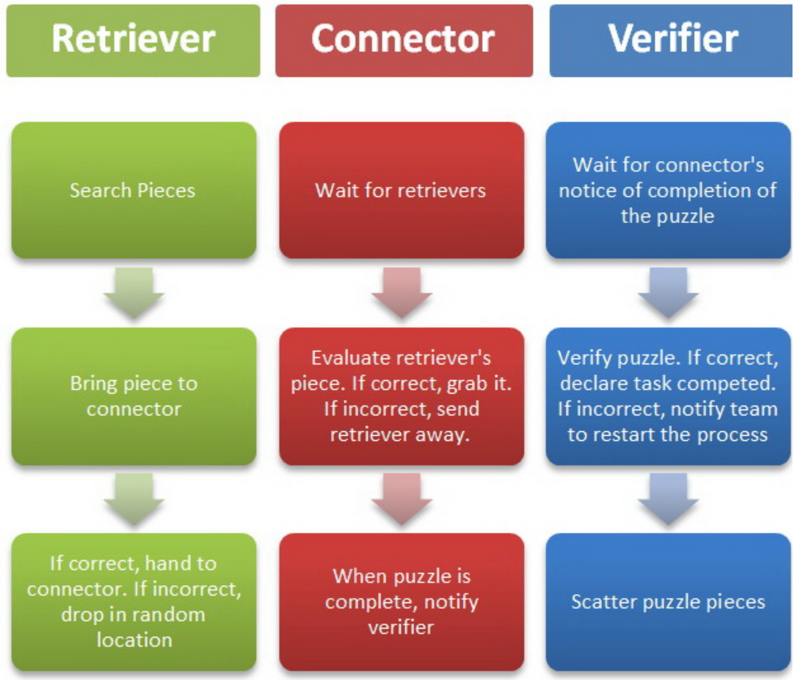


Figure 1. Design rationale for the Stratified Learning Zone agent-based model.

Once the model rationale has been articulated, as above, the modeler couches the agents' rules of interacting with each other and the environment in IF–THEN couplets and packages each topical set of rules in a procedure. These procedures express the researcher's conceptual model. For example, the following procedure (simplified for rhetorical clarity) is for the retriever–connector interaction, and delineates the agent's commands—retrievers gather pieces, connectors receive and evaluate pieces, and retrievers drop unfitting pieces.

```
to retrieve pieces
       ask retrievers
         [
          find-piece-around
          create-link-with chosen-piece
          go-back-to-group

          if any? connectors around me
              [
               if (chosen-piece fits puzzle)
                     [
                      unlink-piece-from-retriever
                      deliver-piece-to-connector
                      update-skill-retriever
                      update-skill-connector
                     ]
              if (chosen-piece does-not-fit puzzle)
                    [
                     go-far-and-drop-piece
                     update-skill-retriever
                     update-skill-connector
                    ]
       ]]
end
```

See http://ccl.northwestern.edu/research/conferences/CSCL2007/CSCL2007.html for an interactive applet of the NetLogo simulation.

Bifocal Modeling: Juxtaposing Real and Simulated Data as a Research Methodology for Iteratively Improving and Evaluating a Conceptual Model

In creating the SLZ model, we worked with videotaped data from the original study. To facilitate the modeling and to iteratively evaluate its "curve fit" to the classroom data, we employed bifocal modeling. We now introduce this methodology and then demonstrate its application to our case study.

Introduction of bifocal modeling

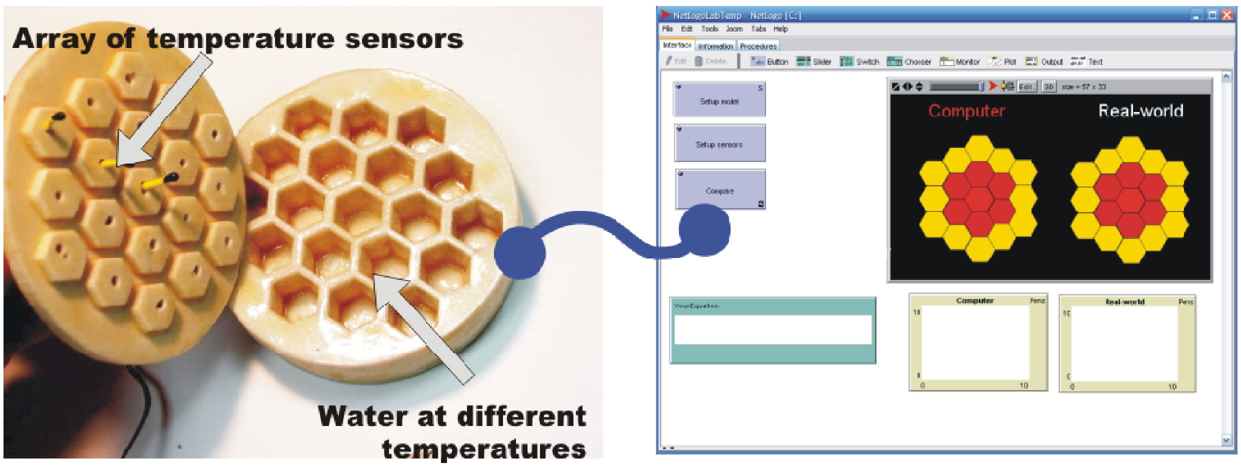
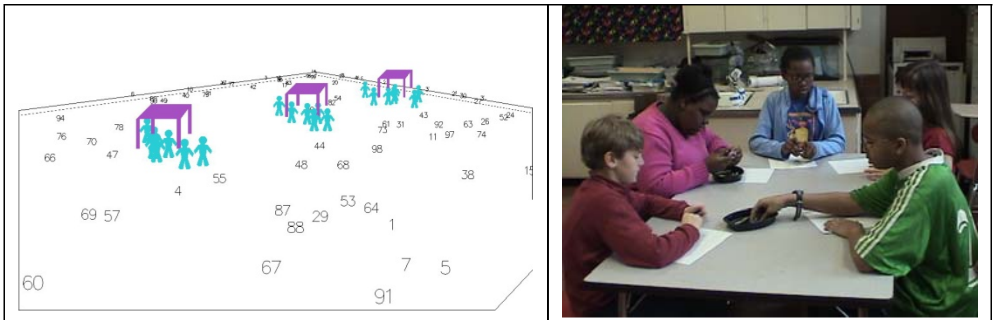


Figure 2. Bifocal modeling: A 'linked' (hybrid) system for real-time physical/virtual investigating of heat transfer.

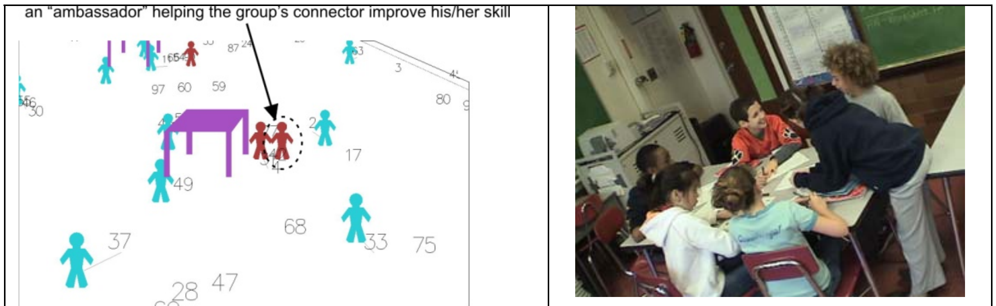
Bifocal modeling (Blikstein & Wilensky, 2006a; Blikstein, Abrahamson, & Wilensky, 2006) combines two ostensibly disparate research practices that are in fact methodologically complementary: agent-based modeling and enhanced visualization. Side by side on a split computer screen (see Figure 2, above, on the right) run the real and the virtual: (a) a movie or graphical representation of a phenomenon under inquiry (whether directly captured by cameras/sensors or enhanced through micro/macro or slow/fast-motion treatment), e.g., crystallization, heat transfer, or clinical interviews with preschoolers engaged in mathematical inquiry (see Figure 2, the physical model on the left, with sensor connecting into the computer and visualized in the 'Real-World' image); and (b) a multi-agent model simulating the same phenomenon in the form of a procedurally expressed and "runnable" scientific model, e.g., myriad interacting avatars representing elements in the conjectured process of annealing or cognitive elements of students' conceptual construction in classroom argumentation. Because the computer models have been carefully constructed to imitate the phenomenon's visual language, the bifocal methodology minimizes interpretive challenges typical of multi-media research. That is, the *seen* and the *hypothesized* are displayed such that their perceptual differences are backgrounded and, therefore, their procedural differences are more likely to be revealed. By thus utilizing the power of computation and representation, bifocal modeling constitutes a multi-disciplinary research tool that offloads aspects of both the interpretive and menial burden of scientific practice, freeing cognitive, discursive, and material resources that can thus be allocated toward validation of the hypotheses. The adaptable quality of the NetLogo multi-agent modeling-and-simulation environment enables users to keep calibrating their proceduralized hypotheses until their visualization reaches compelling micro/macro similarity to the real-data, such that there are grounds to assume that the proceduralized model indeed emulates this phenomenon.

A Bifocal Model of Emergent Collaboration Practices in a Mathematics Classroom

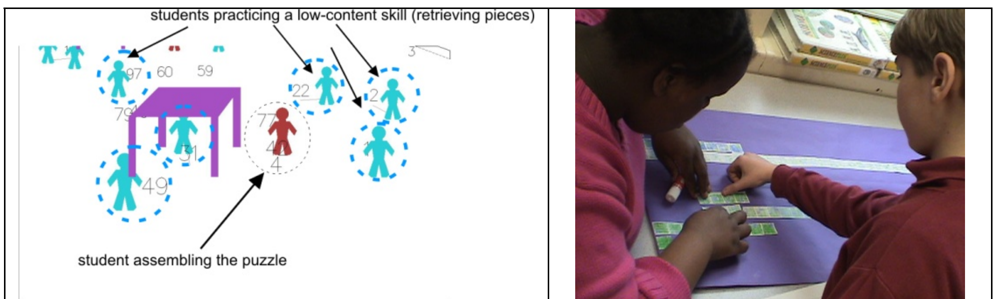
Figure 3, below, shows three examples of real-data (on the right) and simulated data (on the left). Note that our choice to model a generic collaborative activity, rather than modeling the precise activity, makes for surface differences between the real and the simulated data. The comparison is thus analogical: the real sample space corresponds with the linear puzzle, and eight roles in the original data have been simplified to three. In introducing such simplification, one must adopt a skeptical stance, because in any act of modeling lies the inherent possibility that some critical aspect of a situation has been overlooked. And yet, this challenge of modeling is certainly not unique to agent-based modeling but is typical of any scientific endeavor in which a researcher seeks to articulate patterns and mechanisms underlying phenomena under inquiry.



Onset of group work: before the assignment of individual roles emerge.



Student (standing) whose role is to help other groups improve on a specific skill.



Students whose emergent role involves conducting a mathematically trivial skill

Figure 3. Bifocal modeling of collaborative learning: Three samples of paired states in student collaborative practice—computer simulation (left) and classroom data (right).

Findings From the Agent-Based Inquiry Into the SLZ Participation Pattern

We succeeded in simulating the emergence of a stratified learning zone. Furthermore, the model plausibly demonstrates relations between pedagogical practice and student learning, as follows:

a) When student–agents are reinforced for group production rather than individual learning, students become entrenched within skills reflecting their initial within-student skill-level distribution and increase their personal level in those skills.

b) However, when role rotation is mandated, *production slows down yet more learning occurs, per student, in both levels (high- and low-level skills).*

c) A careful analysis of the impact of each task performance on group performance is necessary to build a causal explanation of our numerical results. Indeed, different tasks have diverse impact on overall group performance. Increasing a low-level task skill (i.e., increasing the number of puzzle pieces a retriever–student can bring to the group per time tick) appears to improve group performance linearly (see red line in Figure 4, next page). On the other hand, increasing the high-level task skill (i.e., increasing the probability of the connector–student choosing a correct piece for the puzzle) effects a non-linear trend (see the blue line, in Figure 4).

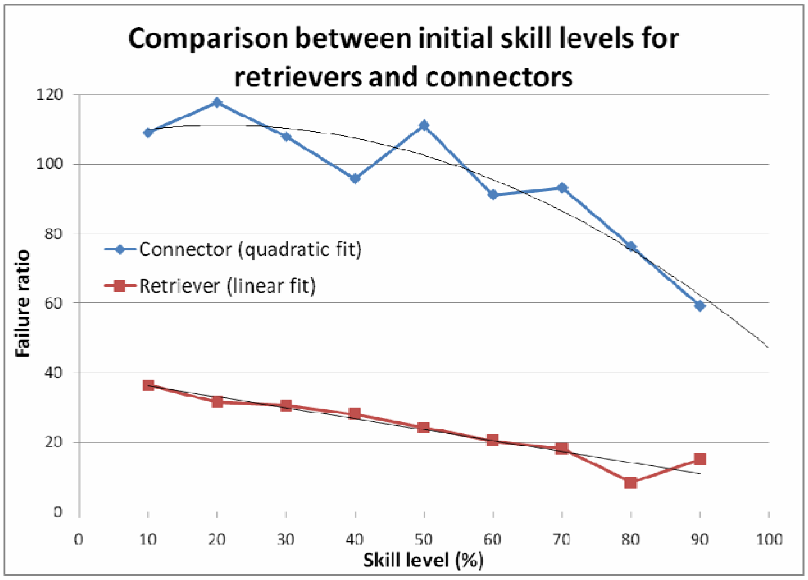


Figure 4. Comparison between initial skill levels for retrievers and connectors. Each data point represents the average of 20 runs of the model with the same initial parameters.

Interaction between different effects of low- and high-level tasks might indicate that the multidimensional combinatorial space of all possible skills levels and types is not a linear *n*-dimensional surface, but might contain discontinuities and multiple local minima and maxima. Specialized functionality of the agent-based environment (*BehaviorSpace*, Tisue & Wilensky, 2004), combined with the bifocaling technique, enable researchers to sketch the topography of this territory, locate minima and maxima, and connect them to real classroom scenarios. For example, the non-linear behavior of connector skills, concurrent with the linear behavior of retriever skills, describe a "hilly" 3-D surface (see Figure 5, below). In some region, slight improvement in connecting skills may significantly impact group performance. Within the same region, improvement in low-level skills renders negligible impact on group performance. This could correspond to a classroom scenario in which one heterogeneous group of students suddenly improves its performance, while other groups, perhaps more homogeneous, still struggle to solve the task at hand. The gain in performance could be attributed to a single student who advanced on a high-level task. Group mates may not have learned the new skill at all, but the group performance, as observed by the teacher, would have improved greatly.

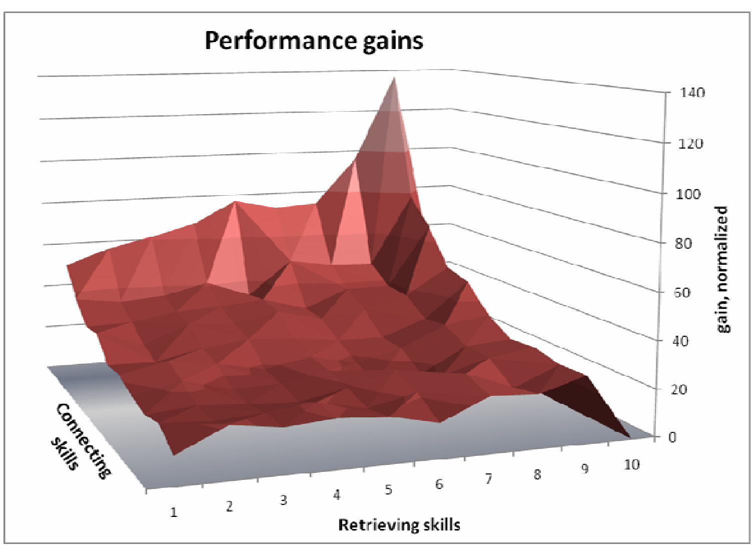


Figure 5. A multivariable experiment, in which both connecting and retrieving skills varied from 1 to 10 (10 runs per data point, for a total of 1000 runs). While still in exploratory stages, this kind of visualization can reveal local minima and maxima, as well as different patterns of performance gains for the combinatorial space of skills.

We are improving the model so as to further examine relations between pedagogy and equity. We are particularly interested to simulate pedagogical practices (e.g., Aaronson, Blaney, Srephan, Sikes, & Snapp, 1978; E. G. Cohen, 1986) so as to understand their underlying mechanisms and gauge their potential.

Conclusions

We have presented a computer-based methodology for conducting research into collaborative learning. To demonstrate the methodology, we described the design and implementation of an agent-based model for studying the emergence of inequitable participation patterns observed in a middle-school implementation of a collaborative-inquiry activity. Based on the functional resemblance of the simulated and real behaviors, on interviews with the teacher and students, and on inter-modeler reliability, we conclude that the model constitutes a viable, if not complete, explanation for the emergence of the observed patterns. We submit that our case study is sufficiently generic so as to shed light on behavior patterns observed in a range of classroom interactions around collaborative projects. We end this paper with remarks on the applicability and limitations of ABM methodology.

Applicability of Agent-Based Modeling to Educational Research

The current study extends our previous modeling-based inquiry into the dynamics of individual learning in social contexts. The inquiry encompasses different "levels" of learning: individual cognition is viewed as arising from distributed dynamics of cognitive elements, and group learning is viewed as arising from distributed dynamics of human elements. An ambitious goal of this work is to combine these two levels of modeling. Such cognitive–social modeling would advance the cause of an integrated learning-sciences theory (Cole & Wertsch, 1996).

Strengths and Limitations

Papert (1980) has demonstrated the intrinsic power of modeling—by virtue of creating a procedure-based model of a phenomenon under inquiry, one has occasion to hone and critique one's own conceptual model of the phenomenon. The application of agent-based modeling to research in the social sciences is still young, and the specific application of this mode of inquiry in the learning sciences is only nascent. Yet we believe in the potential of this methodology. The caveat of proceduralization that agent-based methodology imposes on the researcher can be a humbling experience, because it imperviously demands such clarity and precision as are quite uncommon to the social sciences. Yet once the model appears to plausibly simulate a complex system, it enables powerful exploration. In particular for the social science, where human-subjects issues naturally limit the scope of research, agent-based modeling provides opportunities to investigate the 'what ifs' that are key to fostering change. This study has illuminated for us regions of potentiality that are exciting in their prospects. Of course, in order to validate our findings from the virtual medium, we will have eventually to return to the source phenomenon, where we will evaluate whether the classroom model indeed helps us create a model classroom.

Regardless of the medium in which it is implemented, any model is still just a model—it is an embodiment of a system of conjectures held together through theoretical plausibility, sensed coherence, and empirical support. One must be especially wary in the case of models embodied in dynamic visual media, because the superficial features might divert the researcher from attending to the deep mechanisms ('seduction of sim,' Starr, 1994). It might look and smell like a duck but still be a rabbit. Also, our source study was not designed with a focus on participation patterns within groups, so our video data do not track any one particular group over the entire duration of the implementation, but rather sample from the groups. We can only conjecture as to the group dynamics that transpired in that classroom during the data gaps. In future studies, we will work with data that cover the entire evolution of group dynamics. Finally, student interactions are vastly richer than we have portrayed in our case-study model. A possibly provocative statement is that any theoretical lacuna detected in the current model could be covered by further procedures, such that one could plausibly build agent-based models that capture, if not exhaust, the wealth of learning-sciences theory.

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Learning from virtual interaction: A review of research on online synchronous groups

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Abstract: Although in general collaborative learning is effective, it is clear that this is not always the case. To explain this, researchers have been suggested to investigate the interaction process occurring in the course of collaboration. Research on face-to-face (FTF) groups have provided clues as to what types of interaction are productive for learning, both at the individual and group level. However, the extent to which these findings apply to online groups is not yet clear. This paper reports a conceptual systematic review of recent studies of online synchronous learning groups. There is little evidence that the types of online interaction deemed favorable are actually associated with individual conceptual learning. These findings challenge the implicit assumption held by many educational technology designers. Implications for future research are discussed.

Introduction

Two heads, more often than not, are better than one. This commonsense wisdom apparently applies also to learning: learning in groups is generally more effective than alone (Cohen, 1994; Johnson & Johnson, 2004). However, research has also found that collaboration does not always lead to better learning outcomes (for a recent metaanalysis, see Springer, Stanne, & Donovan, 1999). To explain this, researchers have been suggested to look into the collaboration process (Dillenbourg, Baker, Blayc, & O'Malley, 1995). Indeed, studies have found that certain forms of interaction process are linked to learning. For example, giving explanations during peer-directed mathematics study groups has been found to be related with subsequent individual achievement (Webb, 1982, 1991). Similarly, interpretive talk, but not descriptive talk, between dyads working to solve a programming problem has been found to be related with group performance and individual understanding (Teasley, 1995).

These and other findings (Barron, 2000a, 2000b, 2003; Chan, 2001; Chan, Burtin, & Bereiter, 1997; Kneser & Ploetzner, 2001; Oshima, Scardamalia, & Bereiter, 1996) demonstrate that certain forms of interaction are associated with individual learning and group performance. However, most of these findings come from studies of face-to-face (FTF) groups. Will the same links be found in online synchronous learning groups? What forms of interaction are associated with individual learning and group performance of online groups? These questions are important because many online learning environment and cognitive tools are designed with an eye to facilitating certain forms of interaction, which are assumed to bear learning benefits.

But why should we suspect that interaction of online groups would be any different from FTF groups? We know that different media have different constraints and affordances for communication. Online, text-based communication affords more persistence of information, meaning that previous utterances do not "evaporate" immediately, as they are recorded in the chat environment. On the other hand, it is limited in terms of emotional expressions, deictic gestures, spontaneous response, and eye gaze, which are subtle but important in achieving "common ground" (Clark & Brennan, 1991). Because of these differences, achieving a grounding criterion sufficient for learning to occur would entail a different process for online and FTF groups.

Furthermore, detailed analysis of groups solving complex conceptual problems shows that successful collaboration is based on the co-construction of a joint problem space (Roschelle, 1995). More recently, another study has proposed that collaboration involves two spaces: a *content space* (which is more cognitive and associated with the problem to be solved), and a *relational space* (which more to do with affective and social aspects of interaction, such as identity and conflict) (Barron, 2003, p. 310). For groups to maintain a joint attention that is productive for individual learning and group performance, these two spaces must be coordinated well. How this complex coordination is achieved, once again, would differ with regards to the medium of communication. Thus, it is quite reasonable to examine how interaction and learning links specifically in computer-mediated groups.

Objectives, scope, and approach

This review will focus on studies of online, synchronous learning groups, and thus will extend previous reviews of FTF collaborative or cooperative learning (Cohen, 1994; Webb, 1982, 1991). Unlike most previous reviews, however, the purpose here is not to assess the effectiveness of online collaboration. Instead, this review seeks to examine what kinds of online interaction processes are associated with learning outcomes, both at the individual and group level (group problem solving performance). This was done by systematically searching empirical reports from nine representative journals relevant to the current purpose[1]. In addition, articles from the 2005 CSCL Conference were also systematically searched. The search used several combinations of keywords ("interaction", "collaborative learning", and "computer").

The retrieved articles were then selected based on the following criteria: published recently (from 2000 until mid-2006), report data on both interaction processes and learning outcomes, and investigated online groups communicating synchronously. These limitations excluded many articles that report interaction data but not learning outcome (and vice versa), and studies of groups collaborating asynchronously (e.g., using emails or wikis). This review is admittedly selective and not comprehensive, as the aim is more towards finding conceptual insights than summarizing empirical results (as in meta-analyses). However, the aforementioned criteria were used to limit possible bias or subjectivity on the inclusion of studies from the search.

Description of studies

The selection process resulted in 12 articles, covering 606 groups (1161 individuals). From these studies, 14 separate results can be examined (one article reported 2 experiments, and another article reported 2 different measures of individual learning). A brief description of these studies is given below:

Participants and tasks

Participants were school-aged or university students who worked in pairs or groups of three (triads). The collaboration was relatively short-term, with most studies (9 of 12) using single-session meetings of 40 to 120 minutes. The remaining studies used multiple sessions of 3 to 6 meetings. All but one study used tasks that were domain-related, such as tasks in physics (fluid dynamics), biology (heredity, food chain), psychology (clinical case study and attribution theory), and historical inquiry. One exception, which is a more general problem solving task, was solving a murder case. Some tasks were ill-structured (e.g., writing argumentative essays and constructing a clinical diagnosis), while others are somewhat more constraining (e.g., constructing a concept map using a set of given concepts, or answering multiple choice questions).

Types of learning scaffold

All but one study used scaffolds that were built into the software environment as cognitive tools. One exception is Saab, van Joolingen, & van Hout-Wolters' (2006) study, which used a collaboration script (the RIDE rule) delivered as an instruction prior to the interaction. The rest of the studies used cognitive tools, which can be categorized into script-prompts and external representation tools. Scripts are prompts built into the learning environment that facilitate certain actions, be it epistemic acts (e.g., finding data to ground certain claims) or social acts (e.g., taking a certain role in the interaction). External representation tools vary in their degree of constraint, ranging from very generic and "loose" (such as a virtual whiteboard) to more constraining (such as concept maps and dynamic models).

Approaches to coding interaction data

The coding used by most of the studies reviewed here can be categorized into three approaches. *The first*, simplest way of "coding" interaction is merely counting the number of utterance or message, disregarding the content or meaning of the message. *The second* approach differentiates the content of single utterances

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[1] These are *Computers and Education, Computers in Human Behavior, Cognition and Instruction, Educational Technology Research and Development, Instructional Science, Journal of Computer Assisted Learning, Journal of Educational Computer Research, Learning and Instruction,* and *The Journal of the Learning Sciences*

using a certain categorization. One example is Chiu's (2004) coding, which counted the number of "knowledge-related" utterances produced by learners during a collaborative concept mapping session. A rather more refined example is the coding of "task acts" in van Drie, van Boxter, Jaspers, & Kanselaar's (2005) study, which categorized utterances as on-task, procedural, technical, social talk, or greetings. *The third* approach parses interaction data at the episode level, which is a series of single moves or utterances. Included in this approach is van Drie et al.'s (2005) coding of episodes into domain-specific reasoning, elaborated reasoning, and co-constructed reasoning. It should be noted that these coding approaches were sometimes used in combination by one study. One study (Dillenbourg & Traum, 2006) used a somewhat different approach. Rather than analyzing utterances and episodes, Dillenbourg and Traum looked into degree of grounding (see Clark & Brennan, 1991), as indicated by how often participants explicitly acknowledge that they have understood their partner's move. To summarize, we can differentiate between coding of interaction at the individual/solo action level (single utterances) as opposed to coding at the joint action level (episodes of utterances and degree of grounding).

Assessment of learning outcome

Learning can be assessed at the individual and group level. Assessment of individual learning included declarative knowledge, problem-solving transfer, and reproduction of group problem-solving behavior (e.g., constructing a concept map using the same set of concept and relations). With regard to group performance, we can distinguish between assessment of problem representation produced during collaboration (such as concept map or dynamic model) and problem solution. The problem solution category can be distinguished further into responses to structured tests and construction of artifacts (such as essays).

Results

Results of this review will be discussed separately for learning outcomes measured at the individual level and those measured at the group level (group performance in problem solving).

Interaction and individual learning

There seem to be little evidence that online interaction is actually related with individual learning outcomes (see Table 1). Two studies of groups learning (Makitalo, Weinberger, Hakkinen, Jarvela, & Fischer, 2005; Weinberger, Ertl, Fischer, & Mandl, 2005) found that producing more messages or words during interaction was not associated with higher ability in a near transfer posttest (applying conceptual understanding of Weiner's attribution theory to a new case). Further unfavorable evidence comes from Zumbach, Schonemann, and Reimann (2005), who investigated dyads communicating via a chat to construct a clinical diagnosis of a psychological disorder patient. These authors analyzed the interaction process at the episodic level, looking at action-response sequences defined as collaborative events. No correlation was found between the frequency of collaborative events and individual gain in declarative knowledge test on the topic (depression and anorexia-nervosa), or quality of the clinical diagnosis.

These results are somewhat unsurprising, as the study authors used only a measure of frequency. The first two studies (Makitalo et al., 2005; Weinberger et al., 2005) simply counted the number of words or messages. Zumbach, Schonemann, and Reimann (2005) also did not differentiate between types of collaborative events (although coded interaction at the episode level) and thus lump together short sequences (e.g., simply agreeing to a proposal put forward the partner) with more elaborated sequences (e.g., challenging a proposal and then elaborating reasons for a counter-proposal). However, it is important to note that dyads in one of the experimental conditions did not engage in any collaborative event, but nevertheless achieved high individual learning outcome. This means that collaborative interaction (whether short or elaborated) as defined in this study does not necessary relate to quality of individual learning.

Table 1: Evidence of link between interaction and individual learning

Author (year)	Topic/domain	Coding of interaction	Assessment of learning outcome	Supporting Evidence
(Weinberger et al., 2005)	Theory of genotype environment effect	Utterance content	Declarative knowledge	Positive

(Chiu, 2004)	Heredity, food chain, & atmosphere	Utterance content	Individually reproducing a concept map previously performed collaboratively)	Positive
(Weinberger, Fischer, & Stegmann, 2005)	Attribution theory	Utterance content	Constructing arguments	Positive
			Problem-solving transfer	Negative
(Makitalo et al., 2005)	Attribution theory	Frequency level	Problem-solving transfer	Negative
(Weinberger et al., 2005)	Attribution theory	Frequency level	Problem-solving transfer	Negative
(Zumbach, Schonemann, & Reimann, 2005)	Clinical psychology	Episode content	Declarative knowledge	Negative
			Problem-solving transfer (writing clinical diagnosis)	Negative
(van Drie et al., 2005)	Historical inquiry	Utterance content	Declarative knowledge	Negative
(Saab, van Joolingen, & van Hout-wolters, 2006)	Physics	Utterance content	Declarative knowledge	Negative
			Problem solving transfer	Negative

A further question is whether certain types of online interaction (for example, elaborated or knowledge related episodes) are more associated with individual learning. Results from van Drie et al.'s (2005) study of dyads performing a historical inquiry task facilitated by several different representational forms (diagram, matrix, or list) can be used to address this question. In coding the interaction process, van Drie et al. identified episodes when dyads engaged in elaborated explanations. However, although the matrix and control groups produced more historical reasoning, co-construction, and co-elaboration episodes, they did not perform better in a subsequent individual test on historical reasoning. Similarly, in studying pairs solving problems in a physics microworld, Saab, van Joolingen, and van Hout-Wolters (2006) found that groups who engaged in more "communicative activities", "discovery transformative activities" (e.g., describing and recognizing relations and drawing conclusions), and "regulative transformative activities" did not perform better in declarative nor near-transfer knowledge tests.

Further unfavorable evidence comes from Weinberger et al. (2005), who studied triads communicating via a message board to analyze cases using attribution theory. In this study, groups provided with argumentation scripts produced more counter-arguments and twice as many grounded claims in their messages. This indicates that these group members engaged in deeper cognitive processes related to the learning material. Despite this, no differences were found in individual members' performance in analyzing a new case using attribution theory. However, it is interesting to note the groups using argumentation scripts did outperform other groups in a posttest measuring ability to construct arguments. Thus it seems that although the interaction quality has little influence on domain knowledge, it does have a positive influence on a more general epistemic skill (constructing arguments) that was performed or practiced during the collaboration.

Evidence of this last point can also be found in Chiu's (2004) study of 6th grade student triads constructing concept maps of several domain-knowledge. Students who produced more knowledge-related utterances during their collaboration had better ability to reconstruct the concept map (of the same set of concepts and relations) two weeks after the experiment. Again, this is evidence that relevant interaction during collaboration is related to an epistemic skill (which is, in this case, the epistemic skill of constructing a semantic network) performed during the collaboration.

The only evidence that elaborating knowledge-related material during collaboration is related to acquisition of declarative knowledge comes from Weinberger et al.'s (2005) study of pairs studying a theory of genotype environment effect. Communicating via a video conference channel, students who engaged in more in theory elaborations also gained higher score on a cued-recall test. It is important to note that in this study, the context was a peer-tutorial interaction, which has long been known to be an effective pedagogical approach. Elaborations within this context requires more cognitive processing, as they are performed explicitly or deliberately (explaining and elaborating *is* the group task).

In summary, although certain types of interaction do relate to better ability in performing behavior previously practiced in groups (constructing concept maps and arguments), there is little evidence that they lead to improve declarative or conceptual knowledge. The only exception comes from a study that uses a peer-tutorial scenario and video-conference (i.e. not chat-based).

Interaction and group performance

The studies reviewed provide some evidence for a link between interaction and learning at the group level (measured by a group's performance to produce a solution to a problem, which can be an essay, concept maps, or responses to a set of questions). Some of the studies summarized in Table 2 use multiple indicators for group learning outcome (e.g., essay quality can be measured from its organization, argumentation quality, and audience focus), and thus there can be "mixed" evidence in a single study. As will be discussed, there are several interesting patterns of relationship, again depending on how we assess learning.

Table 2: Evidence of link between interaction and group performance.

Author (year)	Topic/domain	Coding of interaction	Assessment of Learning outcome	Evidence
(van Drie et al., 2005)	Historical inquiry	Utterance & episode content	Essay quality	Mixed
(Erkens, Jaspers, Prangsma, & Kanselaar, 2005)	Organ donation	Episode content	Essay quality	Mixed
(Dillenbourg & Traum, 2006)	Murder case	Degree of grounding	Identifying correct suspect Task management efficiency	Negative Positive
(Chiu, 2004)	Heredity, food chain, & atmosphere	Utterance content	Concept map quality	Positive
(Chiu, Huang, & Chang, 2000)	Computers	Utterance content	Concept map quality	Positive
(Manlove, Lazonder, & de Jong, 2006)	Physics (fluid dynamics)	Episode content	Dynamic model quality	Positive
(Saab, van Joolingen, & van Hout-wolters, 2006)	Physics	Utterance content	Tests of domain-knowledge	Positive
(Saab & Joolingen, 2005)	Physics	Utterance content	Tests of domain-knowledge	Positive

In terms of group learning outcome, we can distinguish between performances in: (1) solving a general logical problem (e.g. a murder case), (2) constructing a textual/linguistic artifact (e.g. argumentative essay), (3) solving a structured domain-specific task (e.g. physics problem), and (4) constructing a graphical external representation (e.g. concept maps and dynamic models). Interestingly, certain types of interaction have a positive effect on the latter two indicators of performance.

In Saab, van Joolingen, & van Houtwolters (2006), performance in solving physics problems is correlated with hypothesis formulation, informative acts, proposing answers, and collecting data in the microworld. Saab and van Joolingen's (2005) earlier study also found similar results. Moreover, these correlations were at the moderate level (0.51 to 0.62). However, they were found only in the experimental groups (not in the control groups), a point that will be returned to later.

Evidence that certain types of interaction influence the quality of graphical representations produced come from three studies. Chiu, Huang, and Chang (2000) found high correlations between on-task interactions with quality of concept map. Chiu's (2004) more recent study also lead to the finding that groups who engaged in more knowledge-related talk also produced better concept maps. In a similar vein, Manlove, Lazonder, and de Jong (2006) found that groups who produced more cognitive episodes in their interaction also constructed better models of a water tank. The correlations between number of cognitive episodes and quality of dynamic model were 0.39 (for experimental groups) and 0.64 (for control groups).

High-quality interaction (e.g. elaboration) does not seem to relate much to group performance in constructing essays (Erkens et al., 2005) or solving a murder mystery (Dillenbourg & Traum, 2006). Both of these tasks are, in a sense, more ill-defined than previously considered tasks. Essay tasks have ill-defined end states (more so than concept maps or dynamic models), whereas murder cases have ill-defined process. However, Erkens did find several weak correlations between coordination processes during collaboration and essay quality. van Drie et al. also found a correlation between co-elaborated episodes with essay quality (r=.66), but only for groups using matrix during their collaboration.

Taken together, these results suggest that certain types of interaction are not directly related to problem solving performance. They are more related intermediate artifacts, such as a group's graphical representation of a problem or a group's efficiency in planning how to go about in an ill-structured task (Dillenbourg & Traum, 2006). However, producing better external representation of a problem, or planning more efficiently, does not guarantee a successful solution.

Discussion and implications

Many CSCL researchers design instructional supports to structure online collaboration with the aim to facilitate certain kinds of interaction. The implicit assumption is that certain kinds (or features) of interaction bear learning benefits. However, the studies reviewed here provide limited support for this assumption. At the individual level, interactions that have been found to be beneficial in FTF groups (e.g. elaborating explanations, co-constructing arguments, and generating grounded claims) do not seem to be related with increase in declarative knowledge or ability to solve problems by applying the conceptual knowledge learnt during collaboration. At the group level, the picture is rather mixed. Certain types of utterance exchanges (episodes) seem to be related to group performance. However, this applies more for intermediate indicators (such as quality of external representation of the problem), but less for end-product indicators (such as essays, which are not representations of the problem, but an end-product of collaboration). Although no conclusive explanations can be offered for these findings, we will try to discuss possible explanations and directions for further research by way of comparison with several published studies of FTF collaboration:

First, many studies of FTF learning groups have found that verbal interaction predicts individual learning gains, even after controlling prior knowledge. Webb (1991), for example, reviewed studies of peer-directed groups instructed to work with mathematical problems. One consistent finding is the positive correlations (controlling for prior math ability) between the frequency of giving elaborated explanations and subsequent individual test. This is in contrast to the relative independence between group processes and individual learning gains found by studies of online groups reviewed here. One possible explanation might be methodological. In most of the studies reviewed here, only one study (Zumbach, Schonemann, & Reimann, 2005) explicitly tested the correlation between measures of process and measures of individual learning outcome. In other studies, this relationship must be inferred from looking at whether groups scoring higher on certain types of interaction also performed better on individual learning. However, this is problematic because these studies aggregated interaction process measures at the group level. For example, an elaborate utterance from one member of a dyad would contribute not only to this particular member, but instead to the dyad's score (the non-contributing member would also be given a score based on his/her partner's contribution). Thus, one direction for future research would be to obtain measures of individual contributions during online collaboration and relate these to individual learning outcomes.

Second, there are several indications that the common coding scheme used to analyze online interaction failed to distinguish utterances reflecting different levels of cognitive activity. This is evident in at least two studies (Saab, van Joolingen, & van Hout-wolters, 2006; van Drie et al., 2005). Saab et al. found that, during collaboration in a physics microworld, utterances reflecting giving information, formulating hypothesis, proposing answers, and collecting data were positively correlated (.51 to .61) with groups' problem-solving performance. However, this was true only for the experimental groups (who were supported with a collaboration scaffold), but not for the control groups. Similarly, van Drie et al. found that the number of co-elaborated episodes a group produced is correlated with its argumentative essay quality ($r = .66$), but this applies only for groups using matrices when constructing their arguments. These indicate that similarly coded utterance or episodes bear different learning consequences, meaning that the coding scheme is somewhat limited in capturing the cognitive value underlying the observable interaction.

One possible explanation is that the "code and count" approach to analyzing group process used in the reviewed studies cannot capture the more emergent properties of the joint discourse. For example, a code and count approach cannot distinguish between two groups producing similar frequencies of a certain type of utterance (elaborated explanation, for example), but embedded in different overall interaction patterns. Several studies of FTF groups indicated that the overall interaction pattern is important. For example, Mercer (1996) noted that groups similarly engaged in a collaborative task can have disputational, cumulative, or exploratory talk patterns (with the first pattern being the least productive for learning). More telling is Barron's (2003) finding from her study of triads collaborating to solve a complex mathematical problem anchored in a video-based story. One of Barron's findings is that groups differed in performance not because none of the members could generate correct solution to the problem. Performance difference was more related to at which point in time during the conversation those correct solutions were proposed. In successful groups, solutions were more frequently proposed in relation with the content of the preceding discussion. This can be interpreted as indicating the importance of sequential structure of collaborative interactions, and call for a sequential approach in analyzing them.

Another way to capture the joint property of group discourse is to use Bereiter's (2002) distinction between problem-centered and referent-centered approaches to knowledge. Using these concepts, we can distinguish between groups who discuss new information as problems to be explained using concepts as tools, and groups who engage in similar discussions but implicitly adopt the goal of accumulating knowledge (which is assumed to reflect reality). Several studies of FTF groups have found that this distinction in how learners approach knowledge corresponds to individual learning and group performance (Chan, 2001; Chan, Burtin, & Bereiter, 1997; Oshima, Scardamalia, & Bereiter, 1996). Whether this distinction is useful for analyzing online collaboration would be another direction for future work.

Third, in contrast to findings from FTF groups, none of the studies reviewed here provide evidence to link interaction through text-based chat with individual mastery of declarative knowledge. A tentative conclusion is that it is difficult to engage in deep cognitive processing in text-based online interaction, especially during short-term collaboration among people who are new to each other. However, (as pointed out by an anonymous reviewer) this will have to be investigated by comparing FTF and online groups using identical materials and measurements. In addition, forms of online interaction do not appear to be related to group performance in joint problem solving. Groups who engage in more meaningful discourse do not necessarily perform better. One possible explanation is that during the collaborative problem solving, groups who did not produce much meaningful discourse achieved similar performance by following their most competent member. This is most evident in one study (Saab, van Joolingen, & van Hout-wolters, 2006), which found a strong correlation between communication asymmetry and group performance among the control groups.

Fourth, there is evidence that text-based online interaction is related with other learning outcomes beside declarative knowledge. In Weinberger, Fischer, and Stegmann's (2005) study, members of groups who produced more grounded claims were better able to construct arguments, which is a valuable epistemic practice. It would be interesting for future research to investigate whether online interaction could help individuals learn other forms of epistemic practices. For example, researchers using concept maps could assess whether participation in collaborative concept mapping helps to enhance an individual's ability to extract core concepts from new texts, or to formulate better guiding questions when comprehending new texts. This is arguably a more meaningful learning outcome than the ability to reproduce the same concept maps from the same set of concepts, as in Chiu's (2004) study. Furthermore, assessment of epistemic practices widens the current focus on domain-knowledge mastery.

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Appendix: Description of empirical studies reviewed

Author (year)	Task context	Participant & interaction time	Learning scaffold	Coding of collaborative interaction	Evidence of link between interaction and learning
(Weinberger et al., 2005)	Peer tutorial via video conference with the goal of understanding a theory of genotype environment effect.	43 pairs (1st year university students). Single session.	Epistemic script (e.g., prompting learners to provide evidence, etc.) & social script (prompting role taking as tutor/tutee).	**Utterance level**: Elaborated utterances, classified into theory elaborations, empirical evidence elaborations, and personal elaborations.	**Individual (positive)**: Dyads provided with social scripts produced more theory elaborations and also gained higher on individual knowledge test (cued recall type).
(Chiu, 2004)	Collaboratively build concept maps from given set of concepts & relations within 3 topics (heredity, food chain, & atmosphere).	32 triads (5th & 6th grade students). Single session of 140 minutes.	Social script that constrain or specify members' role in the concept mapping activity (assigning, rotating, negotiating, and open role).	**Utterance level**: Knowledge-related dialogues.	**Individual (positive)**: The "assign" group produced more knowledge-related talk than all other groups, and performed better in individual knowledge test. **Group (mixed)**: Although the "assign" groups produce more knowledge-related talk, they did not outperform groups in the "give" and "open" conditions. Nevertheless, the "assign" groups outperform the "rotate" groups.
(Weinberger, Fischer, & Stegmann, 2005)	Analyzing 3 cases using attribution theory (e.g., explaining the attribution of a boy about his difficulty with mathematics.	40 triads (1st year university students). Single session of 80 minutes.	Two kinds of argumentation scripts: one designed to foster the construction of single arguments (a text-box for "claims", linked to a text-box for "warrants" and "qualifiers"), and the other for constructing argumentation sequences (much like a dialectical process, going from arguments, counter-arguments, integration, etc.)	**Utterance level**: Single messages were classified based on two dimensions: argumentative and epistemic. In the argumentative dimension, grounded claims (as opposed to simple claims) & counter-arguments were counted. In the epistemic dimension, number application of prior knowledge & new knowledge were counted.	**Individual (mixed)**: Groups given the Single Argument Script produced more counter-arguments & twice more grounded claims than control groups. This is associated with a higher score in a posttest measuring ability to construct single arguments. The Argument Sequence Script groups also produced more counter-arguments, & more instances of prior knowledge application compared to control groups. This is associated with higher posttest score on construction of argumentative sequences. However, no differences were found regarding posttest performance on domain-knowledge.
(Makitalo et al., 2005)	Analyzing 3 cases using attribution theory (e.g., explaining the attribution of a boy about his difficulty with mathematics.	16 triads (university students). Single session of 80 minutes.	Epistemic script designed to guide the case analysis by giving prompts as to what kinds of information to look for.	**Frequency level:** Simply the amount of discourse or number of words produced during the interaction.	**Individual (negative)**: Groups provided with epistemic scripts produced more discourse, but achieved lower in their individual ability to apply attribution theory into a new case (in the posttest).
(Weinberger et al., 2005)	Analyzing 3 cases using attribution theory (e.g., explaining the attribution of a boy about his difficulty with mathematics.	32 triads (1st year university students). Single session of 80 minutes	Epistemic script (see above), and social script, designed to foster collaboration by prompting role taking in the discussion.	**Frequency level**: Simple the number of messages exchanged during the interaction.	**Individual (negative)**: Groups with social scripts produced fewer messages but achieved higher in their individual knowledge test (applying attribution theory to a new case).
(Zumbach, Schonemann, & Reimann, 2005)	Constructing a clinical diagnosis of a patient with psychological disorder.	20 pairs (university students). Single session of 90 minutes.	Feedback as reinforcement of collaboration between partners.	**Episode level**: Certain action-response sequences were coded as collaborative events, which covers relatively short or simple action-response sequence, to more elaborated or complex sequences. Thus, sequences coded as collaborative events were not of equal "quality".	**Individual (negative)**. Number of collaborative events did not correlate with gain in individual knowledge test, nor with quality of clinical diagnosis.
(van Drie et al., 2005)	Historical inquiry task to argue whether or not the changes of Dutch youth in the 1960s were revolutionary, followed by an essay writing task (1000 words).	65 pairs (pre-university students). 6 lessons of 50 minutes.	Different representational forms (diagrams, matrix, and list) designed to facilitate construction of argumentation.	**Utterance level**: Chat was coded based on content, into on-task (including historical reasoning category), procedural, technical, social, and greetings. **Episode level**: Historical reasoning utterances were further coded into episodes, grouped into: domain-specific reasoning, elaboration, and co-construction. The last two were	**Individual (largely negative)**: Although the groups using matrix and control groups produced more historical reasoning, elaboration, co-construction, and co-elaboration (compared to diagram & list groups), they did not performed better in individual post-test of historical reasoning test. **Group (mixed):** The matrix groups did not produce better essay quality. However, there was one significant correlation, which is between number of co-elaborated episodes with essay quality (r=.66), but this was observed only in the matrix group, and not in any other groups.

				combined into a measure of "co-elaboration" episodes.	
(Saab, van Joolingen, & van Hout-wolters, 2006)	Discovering physics laws behind a computer simulation (*Collusions*). Pairs are presented with assignments which require them to experiment or collect data in the microworld.	29 pairs (secondary school students). Single session of 90 minutes.	Instruction on effective collaboration or communication using the RIDE rule (Respect, Intelligent collaboration, Deciding together, and Encouraging), which is also embedded in the online learning environment (pop-up windows prompting certain actions).	**Utterance level**: Utterances and actions categorized into communicative activities (consists of informative, argumentative, elicitative, responsive, directive, and off-task), discovery transformative activities (consists of orientation, generating hypothesis, testing hypothesis, and concluding), and discovery regulative activities (consists of orientation, planning, evaluation, and monitoring).	**Individual (negative)**: Even though the experimental groups engaged in more communicative activities (in terms of deciding together and encouraging acts), discovery transformative activities (in terms of describing & recognizing relations and concluding acts), and discovery regulative activities, they did not perform better in a declarative nor "what-if" knowledge posttests. **Group (mixed)**: Within the experimental group, score in the assignments during collaboration were positively correlated with informative acts (r=.51), formulating hypothesis acts (r= .61), proposing an answer (r=.55), collecting data (r=.55), while correlating negatively with off-task technical acts (r= - .61) and describing & recognizing relations (r=. – 58). In the control groups, score of assignments correlated positively with asymmetry in communication (r=.61), indicating that control groups performed as good as experimental groups because they "followed the leader". This further indicates that group scores is not a good measure of effectiveness of collaboration, because it is highly influenced by the free-rider phenomenon.
(Erkens et al., 2005)	Analyzing information sources to construct an argumentative essay (600 – 1000 words) about organ donation issue.	145 pairs (high school students). 4 – 6 lessons	TC3 (Text Composer, Computer Supported and Collaborative): includes a database of information sources, a private notepad, and a chat facility, plus a certain type of planning tool for writing (argumentation diagram for content generation, and outline for content linearization).	**Episode level:** Chat protocols were coded in 2 broad categories: content-related and writing strategies (Task Acts) and communicative-coordination process (Coordination Process). Task Acts are parsed into planning, executing, and non-task. Coordination Process consists of focusing, checking, & argumentation processes.	**Group (mixed)**: Some weak correlations were found: (a) focusing processes correlates with textual structure of essay (r=.14) and with overall argumentation quality (r=.12), and (b) argumentation processes correlates with overall argumentation quality (r=.13). However, several unexplained correlations were found, particularly some negative correlations between planning acts with text quality (in the control groups).
(Dillenbourg & Traum, 2006)	Solving a murder case: finding the killer from a number of suspects by inferring from clues (e.g., motives, opportunity, etc.).	18 pairs (mostly postgraduate students). Single meeting of 82 – 182 minutes.	Shared whiteboard and MOO environment (text-based virtual reality, in this case includes a virtual map of a hotel, several characters, and objects).	**Degree of grounding**, as indicated by how often pairs explicitly acknowledged their understanding of their partners verbal or other moves.	**Group (mixed)**: The degree of grounding in groups who succeeded to find the murderer did not exceed groups who didn't succeed. However, there is a difference in task management efficiency: the more pairs acknowledged understanding (the more grounding), the more efficient they are in managing or planning the problem solving process.
(Saab & Joolingen, 2005)	Discovering laws of physics by experimenting in a micro-world (to answer open-ended and multiple choice questions).	25 pairs (10th grade students) Single session of 90 minutes.	A tool facilitating hypothesis construction by presenting elements such as variables, plus an evidence palette supporting externalization & evaluation of reasoning.	**Utterance level**: Classified into communicative acts, discovery transformative acts, and discovery regulative acts.	**Group (positive)**: Dyads' performance in solving assignments in the microworld is correlated with the following acts: deciding together (r=.62), transformative (r=.55), & regulative (r=.53). These correlations were found only in the experimental groups using the hypothesis tool.
(Manlove, Lazonder, & de Jong, 2006)	Building a dynamic model of a water tank system (a case in fluid mechanics).	19 triads (high school students). 3 meetings of 60 minutes.	Regulative directions of planning, monitoring, and evaluating problem solving/learning collaborative processes.	**Episode level**: Utterances were grouped into episodes, based on content, into cognitive episodes, regulation of collaboration episodes, and regulation of learning task episodes.	**Group (positive)**: Cognitive episodes appeared more in the treatment groups compared to control groups. The treatment groups also produced better models. Correlation between cognitive episodes with quality of dynamic model was 0.39 for the experimental group and 0.64 for the control groups. However, regulation of collaboration episodes correlated negatively with quality of dynamic model (in the control group, r=.-66), and regulation of learning task episodes correlated positively (r=.81) in the control groups, but negatively in the experimental groups (r=.-59).
(Chiu, Huang, & Chang, 2000)	Constructing a concept map on "central processing unit" with 11 given concepts. Only one member of the triad can manipulate concept map. Triads can also request a feedback score of their concept map.	12 triads (university students). Single session of 80 minutes.	Collaborative, networked concept mapping tool, plus a scoring facility (comparison of group concept map with expert concept map).	**Utterance level**: Grouped into cooperation (simple and complex), helping (explaining, answering, and informing), and social event behaviors.	**Group (positive)**: The following interactions were correlated with quality of group concept map: number of chat utterance (r=.851), on-task utterances (r=.799), cooperation utterances (r=.754), high-level interaction (r=.872), and complex cooperation (r=.872).

Drawing on Practices for Modeling Socio-Technical Systems

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Abstract: The formal description of pedagogical scenarios and learning processes has attracted a lot of attention among researchers and developers in recent years. Nevertheless current modeling approaches resemble the notion of workflows and hence fall short in describing the situated and socially mediated nature of practice. Against this background the paper describes an alternative modeling approach as well as its theoretical foundation and practical implications.

Introduction

The formal description of pedagogical scenarios and learning processes has resulted in a couple of specifications focusing on individual as well as collaborative activities. The explicit and formal representation of educational processes is relevant for quite diverse reasons. Besides their technical and economic relevance they also provide a tool of communication as they allow to share experiences and to coordinate activities among those involved in the design and development process. Furthermore they are of interest for learning scientists as they provide a frame of reference for the analysis and comparison of different scenarios. While current educational modeling languages such as IMS Learning Design (IMS, 2003) overcome the problem of de-contextualized learning objects by describing the use of these objects within a unit of study, they resemble traditional workflow models and hence reproduce the problem on a higher level. Even though these approaches acknowledge the complex nature of learning processes they are reductive (the educational process equals the sum of the learning activities entailed). Thereby the situated and socially mediated character of human action is neglected. Against this background this paper outlines an alternative modeling approach which draws on activity theoretical as well as systemic theories to depict practices. The paper is structured as follows: Key assumptions of the cultural-historical activity theory (Leontjew, 1978) as well as the Theory of Social Systems (Luhman, 1995) are introduced to outline the underlying rationale of the modeling approach. Referring to the theoretical foundations the modeling approach is presented. In a further work the modeling approach is presented in details and the practical implications are discussed.

The Concept of Practice

The concept of practice can be defined as "the ways of doing work, grounded in tradition and shared by a group of workers" (Bødker, 1991). While the concept of practice can basically be defined as a customary way of doing things, it seems worthwhile to have a closer look at this concept from a theoretical point of view. The following is a list of key-assumption on human-activity and social systems. Here we state, that the concept of activity systems and social systems hold common assumptions.

Key assumptions of activity theory (AT): AT is a philosophical framework and descriptive tool focusing on understanding human activity and work practices. It is based upon the psychological theory of A. N. Leontjew (1978) and L. S. Vygotsky (1978). (1) Human activity is object-oriented, i.e. it is directed towards a physical or conceptual object that is transformed by the activity. It is the *object of an activity* and not the goal that allows distinguishing different activities from one another. Artifacts are not objects by themselves, but can become an object of activity when they are targeted and transformed in the course of an activity. The difference between an artifact in the sense of a real entity and the object of an activity is crucial as one and the same artifact can be used for a multitude of different purposes in different activities, while the object of activity is unique for every activity. (2) Activities are always mediated by tools and signs, which are constitutive elements of the activity system. Tools and signs are mediators which range from physical to conceptual artefacts (e.g. knives, plans, spreadsheets, scientific theories, and languages). Tools capture and preserve the socially shared knowledge developed in a given community and mediate the subjects' relation with the object of the activity as well as with other human beings (cp. Leontjew, 1978; Stahl, 2003). (3) Human activity whether carried out individually or collectively cannot be detached from its social context as its meaning is bound to its interpretation within a collective. (4) Activities are shaped by contextual conditions and circumstances. Human activity has to continuously adapt its actions and operations to external events and circumstances. As a consequence human activity is guided but not predefined and determined by plans (Bardram, 1997). (5) The relationship between subjects, objects, and tools is reciprocal. The elements within an activity system are mutually interdependent, which means that a change in one of them will inevitably alter the other ones. In this sense the constituents of an activity form a system where each component is defined in relation to the other components. (6) According to Leontjew (1978) three levels of activity can be distinguished, namely collective *activities* which are carried out on a communal level often involving multiple actors, *actions* that are performed by a single subject to achieve a certain goal relevant to the collective activity, and *operations* in the form of fine grained automated routines. But even though activities are structured hierarchically Leontjew notes that the relation between operations and actions as well as actions and activities is not an additive one. Therefore it is not possible to simply decompose an activity into a set of actions. The difference between a set of actions and an activity is not a quantitative but a qualitative one. (7) Practices are never static but evolve when contradictions or tensions emerge between the elements in an activity system. Due to the systemic nature of practices changes in one element or the relation between elements usually affect the entire system. Due to their dynamic nature practices are historical entities in the sense that they change and develop in time.

Key assumptions of the Theory of Social Systems (TSS): TSS (Luhmann, 1995) is a descriptive framework presenting a system-centered view and a non-deterministic and non-prescriptive meta-theory. It is a variant of the General System Theory (e.g. Parsons, 1951). Parsons (1951) argues that societies as well as biological organisms aim at homeostasis (maintaining a stable state), and that their parts can be understood only in terms of the whole. (1) The difference system/environment is the central paradigm. The TSS describes the world in terms of systems, drawing a difference between a system and its environment. Whereas e.g. in object-oriented modeling objects and categories are defined, the TSS states that the difference system/environment is constructed. “The central paradigm of recent system theory is ’system and environment’. The concepts of function and functional analysis no longer refer to ’the system’ (...) but to the relationship between system and environment.” (Luhmann, 1995). The difference system/environment is not ontological but an epistemological. “This leads to a radical de-ontologizing of objects as such (...). This interpretation contains no unambiguous localization of any sort of ’items’ within the world, nor any unambiguous classifying relation between them.” (Luhmann, 1995). (2) Personal systems as well as social systems are meaning processing systems as they are processing information by constructing meaning. A social system is not the group of people it contains. The social system is of different quality as there are different levels of emergence. Meaning is processed according to the actual state and current structure of the system and is defined by the system itself. (3) Persons (personal systems) do not belong to a social system but to its environment (Luhmann, 1995). This means, a person (and any other entity/type) does not belong to a system for all intents and purposes but in some respect, filling a specific role. Thus, a system can not determine another. (4) Elements within a system generate each other, e.g. in listening, the audience creates the speaker and vice versa. (5) Systems organize their inner complexity and reduce contextual (environmental) complexity. Systems are closed and self-regulated. Processes are inherently in-determined from an observer’s point of view.

Modeling (Knowledge) Practices as Coherent Social Systems

This section outlines a modeling approach for modeling socio-technical systems. As this paper rethinks the epistemological foundation of modeling socio-technical systems, the approach goes beyond specifying specific concepts and relations and addresses the meta-level of modeling. The approach is based on three major inputs. (1) Distinguishing the meta-level categories `natural type` from `role type` to distinguish between an object and its role within a specific context/system (Guarino et al., 1994; Steimann, 2000), (2) introducing a system-centered perspective to reduce complexity and to model elements which generate each other within a system (`n-ary relations`), and (3) integrating basic assumptions of AT in order to overcome shortcomings of workflow models which work as means-end-models (different `levels of emergence`). Guarino et al. (1994) provide an ontological distinction, separating the meta-level categories `role types` from `natural types`. This distinction is based on the meta-properties identity and rigidity. Natural types (types) are semantically rigid (an instance of a class once and forever belongs to that class; it cannot change it without loosing its identity) and not founded. Role types (roles) are not semantically rigid (instances of types can fill, adopt and leave a role without loosing their identity) but founded (defined by context and relation). In figure 1 a rectangle indicates a type, a circle indicates a role, e.g. an instance of the type *artifact* fills the role *tool* within a specific context/system. Guarino et al. (1994) and Steimann (2000) define the meta-level category `role type` (role) as a binary relation. A role is defined by its relation to another role. We state, that roles within a system are reciprocal and mutually interdependent as elements within a system generate each other. Thus, this work models *action* and *activity* as `n-ary relation`. Furthermore, action and activity are modeled on different `levels of emergence`. The modeling approach takes into account several key assumptions of AT and the TSS and has practical implications: (1) Activities (such as learning) are contextualized (distinguishing between role- and type-based attributes of the entities involved). (2) Activities can not be de-composed and reduced to a chain of actions without a loss of information (the relation operations/actions as well as actions/activity is not an additive one). Current modeling languages treat activities as self-contained entities related to other activities via respective pre- and post-conditions (organized hierarchically, sequentially or in parallel). (3) The elements of a system generate each other reciprocally. It is important to note that the model described so far is a meta-model providing the semantics but not the syntax of a respective modeling language. Accordingly the aim is not to demonstrate the practical utility of a particular modeling language but the general implications of the meta-model proposed. Further work is to be done in specifying a modeling language (based on the meta-model presented in this paper) to describe practices and socio technical systems in the field of CSCL and CSCW.

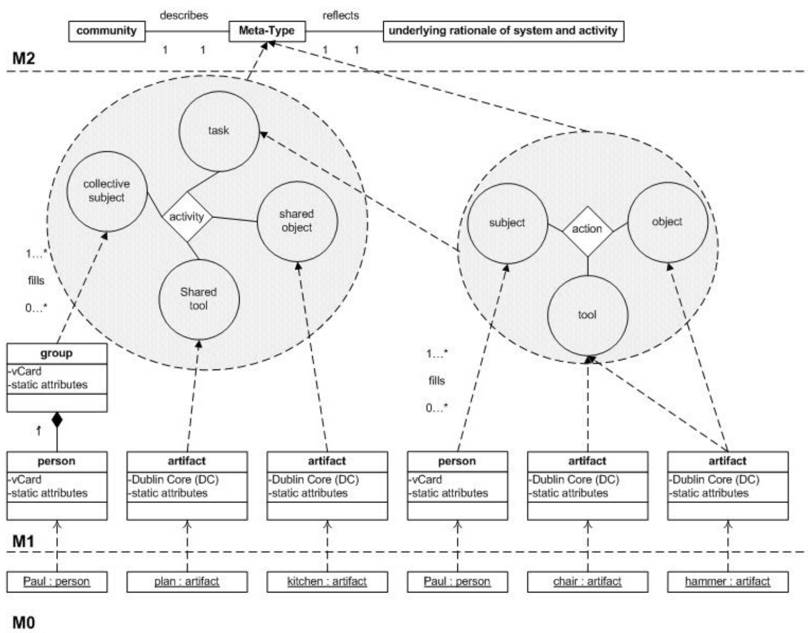

Figure 1: The meta-model of a system-centered role-based modeling approach, in UML.

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Technology in a Context: Enabling students to collaboratively participate at the interface of computation and social science

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Abstract: This paper explores the use of *reflective collaborative technology* to organize the collaboration within a class so as to produce computer science students who learn to develop technology within a critical framework. A case study is presented that shows how technology can be used to produce objects of reflection and analysis for the multi-disciplinary theoretical analysis of online activity.

Introduction

For a number of years the first author has been teaching a suite of courses in a Computer Science department that try to put computation, and technology in general, in a context. The culture of Computer Science tends to be antithetical to any kind of critical stance towards the analysis, design, engineering, and deployment of technology. In Computer Science, theory is equated to formalization and practice to technique. The context of computation, the actors and their various concerns, the interface of technology, social science, and the humanities, is mostly ignored or trivialized. Students trained in this tradition are not easily coaxed into exploring the interface of technology with disciplines outside the sciences, nor do they as a group appreciate the rigor of non-formal theoretical work. The standard model of teaching in Computer Science is to douse students with a fire hose of technology and information. Students learn to organize and retain information despite very high baud rates of information. This approach to education is not conducive to either a critical stance or reflection, both of which are requisite for learning at the interface of technology and social science. A different pace of action – with opportunities to pause and reflect, be discursive and thoughtful – is required for an educational practice that invites reflection.

Students outside of computer science would also benefit from a more reflective approach to learning about technology in a context. Examples of the set of tasks, topics, and fields that compose this second population are informatics, library research and the digital library, computer supported cooperative work, the internet, graphic design, scientific visualization and animation, education, and economics and business. These students require a basic understanding of computation/internet as an important form of mediation, how computation functions in a context, but they also need to be able to use the technology to mediate their work and to understand the context of the technology. For these students, there exists a very interesting relation between the object of study (technology) and the means of study (technology): it is reflective.

This paper will focus on the use of collaborative groupware technology to explore the interface between technology and social science. The use of *reflective collaborative technology* helps students to practice with alternate disciplinary frameworks, developing multi-disciplinary ways of orienting and methods of operation. The basic idea is to have students work online, record their work into transcripts that are reviewable, and then analyze the transcripts. This serves a range of theoretical and practical functions. The reflective technology enables students to exploit the reflective relationship between what they are learning and how their learning is mediated. Other efforts on the role of technology in reflection and education have emphasized how computers can support student reflection as the students learn the course material (Collins & Brown, 1988); for example, in a knowledge-building community (Scardamalia & Bereiter, 1994) the technology supports students as they reflect and construct new knowledge relevant to the content of the course, say environmental studies. Reflective technology, of the sort that we are interested in, gives students reviewable transcripts of their online activities, and these transcripts are directly relevant to their education about technology.

All of the collaborative platforms we have developed in our lab produce transcripts of user behavior that are reviewable and replayable. The production of transcripts of online collaborative behavior serves a range of theoretical and practical functions:

1. The exercise of collecting transcripts teaches experimental design and methods.
2. The participation of the students in data collection exercises gives students first hand experiences with online collaboration.
3. The first hand experience of the students as both collectors of data and participants in online collaboration are an object of reflection.
4. The transcripts provide concrete data for exploring and evaluating a theoretical framework.
5. The transcripts are a source of design problems and also a testing ground for design innovation.
6. The transcripts provide concrete data for teaching and practicing various kinds of analysis methods.
7. The collection of transcripts is a shared repository of data for term projects.
8. The transcripts are a basis for classroom discussion.

Integrating Reflective Technology into the Classroom

This paper presents a case study of a class at Brandeis University that used collaborative technology as a foundation for course material that puts technology in an interdisciplinary context. The case study reprises the details of a course that taught multi-disciplinary theories of intersubjectivity to computer science undergraduate and graduate students. In this course, technology was used to record the student's own online collaborative activity in a representational form that was reviewable and thereby accessible as an object of analysis and reflection. The use of the collaborative technology gave students first-hand experience with the object of study, supporting student learning for the entire range of research and development activities, both theoretical and practical, from theory, to method, to evaluation. The class was composed of a mix of graduate (13) and undergraduate (15) students. The material in the course was conceptually difficult.

The first part of the semester was spent working through a demanding reading list, especially for the computer science students whose orientation is primarily technical; the topic was intersubjectivity. Making this kind of interdisciplinary theoretical material relevant to a class of students who are largely computer scientists is not a trivial task. The material is relevant to the technical development of online environments that support collaborative effort within a community. If nothing else, the theoretical material explains why many network-mediated activities or organizations think their virtual community is an impoverished form of collaboration when contrasted to communities that regularly meet face-to-face. But the theoretical material has more relevance than that. The first step towards integrating mediated forms of interaction into emerging or existing communities of practice is to understand the requirements. Only then is one in a position to design and engineer environments that best match the practice given the constraints of the technology. Other value can also be achieved by understanding what cannot be done and why not. It is also a bit of a surprise for computer science students to discover that what occurs online is a significant source of data for navigating safe passage through contentious theoretical waters.

During the second part of the semester the students practiced methods of transcript analysis. The last part of the semester was a workshop where the class collectively worked at reading transcripts as they proceeded with their term projects; the class also continued to read papers. The use of collaborative technology to create objects of reflection and analysis was critical to the development of the students' practice.

The class used wiki-based technology called CEDAR throughout the semester. CEDAR enables students to collaborate same time/different place vis-à-vis a wiki. It provides students with a set of "What You See Is What I See" (WYSIWIS) components: a public chat, shared Wiki editor, shared web browser, and a document overview that displays a map of the Wiki structure that the users create and maintain. Replayable transcripts of online user activity are automatically recorded. A replay device enables students to review their online activity as if they were viewing a videotape.

CEDAR was initially introduced to the students one month into the semester. CEDAR was used to give the students some hands-on experience with online collaboration and prepare for data collection exercises. The class was divided into teams of 2 to 5 students who engaged in a collaborative task. Because CEDAR was still in beta stage, these exercises provided an opportunity for some motivated discussion of design for use. The data we collected was used for exercises in class that forced students to apply various kinds of transcript analysis methods. Analysis of the data was also featured on the exam that assessed their skill at applying the transcript reading techniques they had been taught, and provided a basis for term project proposals.

During class, the initial set of data was replayed to apply theoretical concepts to concrete data and teach the students the transcript reading techniques. The initial replay device was very slow, so it was rebuilt. Some of the students created additional tools for analyzing the transcripts: shell scripts extracted and displayed the chat among the users in chronological order; they also produced logs of the users' activities at the level of "He is chatting" or "He downloaded a file".

Students were encouraged to bring their laptops to class so they could break out into smaller groups and practice transcript analysis. The initial set of data was also used as a basis for their term project proposal. Each proposal was required to include at least one segment of transcript to illustrate their idea. Examples of topics include: visualizing awareness between participants, division of labor, interruptions, and leadership within groups.

The class engaged in a redesign task. The plan was to redesign CEDAR for a second set of data collection exercises. Time constraints limited the changes that could be made to CEDAR. As a result of class discussion, two additional features were implemented. The data collection exercise was modified so it would provide a more interesting set of data. The goal here was to prevent the employment of a "divide-and-conquer" strategy among the team. This would encourage more interaction and joint sensemaking among the users. These uses of the technology helped the students to develop the scientific practice of experimental design. They also enabled the students to produce data that would improve their project results.

The class collected a second set of data using the new task and the modified version of CEDAR. This exercise provided the students with a more carefully engineered set of data that better supported their term project work. It also completed the redesign cycle by presenting the class with the opportunity to critically reflect on the tasks of interface design and experimental design.

Some analysis was done of the effect of integrating the production of objects of reflection and analysis into the framework for the course. The range, scope, and quality of the term projects provided significant evidence that using collaborative technology to support reflection enabled students to participate at the interface of computation and social science. With but a few exceptions, the term projects uniformly demonstrated significant progress at understanding the theoretical topics discussed in class. The projects showed that the students were able to take abstract theoretical ideas and apply them to the close analysis of detailed transcripts of online activity. Without the in-class participation and practice at reading and analyzing transcripts, showing the relevance of theory to the dynamics and concreteness of online activity, it would have been much more difficult for students to make the leap – much of the class would have been lost.

At the end of the semester we handed out a survey to the students asking theoretical and practical questions about the course topics and structure and the value of the CEDAR technology. 93% of the students said that the CEDAR technology is useful for studying and applying the theoretical topics covered in the class. 82% of the students stated that having access to replayable transcripts made the theoretical papers read in class more comprehensible. 79% thought the availability of transcripts was helpful in choosing a topic for their term project. 82% believed that the second set of data was more relevant to their term projects. 75% believed that transcripts helped to focus the interface redesign task.

The survey also yielded the following representative comments from the students: "It helps you understand the task better to do it yourself. It gives more insight into how groups collaborate, how joint sense is achieved. It is easier to look at data from a task you are familiar with." "When we see the transcripts, the examples correlate with the theoretical stuff we read about. We can relate examples we see to the theory and challenge the theory." "Some of the papers were clarified or made concrete by examples from our transcripts."

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Supporting Collaborative Learning in Online Higher Education through Activity Awareness

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Abstract: Improving activity awareness, the ability to know what is going on around you in ways that are meaningful to your learning objectives and activities, in online learning has the potential to enhance the effectiveness of online learning for students and instructors. This paper introduces readers to the Context-aware Activity Notification System being developed for use within course management systems. [60]

Introduction

Online learning is becoming a pervasive part of higher education. However, while online learning plays a powerful role in broadening access within and beyond campus sites, there is a growing concern that it may be diminishing the quality of teaching and learning by forcing instructors and learners to view courses through the narrow pedagogical lens afforded by contemporary software systems. There is potential, however, for making the pedagogical aspects of online courses rich, effective and efficient, but this potential depends on improving online learning so it is active and social without making it more complex or technologically intrusive. Activity awareness, while a difficult objective to achieve, has great potential for supporting more active and social online learning. This paper briefly introduces the reader to the Context-aware Activity Notification System (CANS) being developed for the Sakai community and potentially for use within other course management systems, and to the objectives of a three-year project funded by the Fund for the Improvement of Post-Secondary Education (FIPSE).

The Need for Activity Awareness in Online Higher Education

Students learn in a variety of ways, including listening to lectures, writing papers, reading texts, undertaking projects, and discussing issues. Instruction provides explicit guidance for what to do and how to proceed. Given appropriate conditions and resources instructors can guide students to work individually or more collaboratively on their assignments. Additionally student motivation and tacit knowledge that comes from the instructional and social context also shape the “what to do and how to proceed” decisions that students make.

Today’s approach to online learning is encapsulated in course management systems (CMS) of which Blackboard, WebCT and Sakai represent popular applications. These CMS provide fairly effective ways for instructors to give and control access to information about a course (syllabus, assignments, grades) and about the subject matter (instructional resources). They also provide some facilities for direct interaction through discussion boards and chat rooms, and in various other ways try to support forms of interaction. These approaches help manage the course but are very limited in how they help teach the course or support learning. In many ways the CMS is a black veil between the instructor and students and among the students. Faculty and students are limited in their knowledge about what is happening in the course to the “words” spoken. Students do not see other students working; nor for the most part do they see each other’s products. Instructors do not see students working and can only influence them with words. The incidental learning that happens through working together, the social learning that happens through observing others, and the motivation to keep learning that happens because of a sense a shared social experience are greatly constrained. Instructors often impose artificial tasks such as requiring a number of postings to a discussion board to force some minimal level of engagement. Students quickly “learn” to only complete tasks that are directly related to course assessments and all too rarely become engaged in dialogue to enhance learning.

Learning in CMS does not provide attributes and cues that normally help motivate and tacitly shape face-to-face learning. Expert online instructors try to make up for these deficiencies with engaging tasks and emphasizing the social and collaborative nature of learning, but in general CMS are deficient in many of the cues that are important to motivation and for having activity help shape learning. By providing information about what others are doing (who is online, what are they doing, etc.) and what is happening (what documents are being read, what activities have been completed, etc.), we predict that collaborative learning can be better supported in online higher education and will be viewed as substantially more effective, acceptable and sustainable for instructors and students.

INNOVATION

Awareness and Notification

Information systems need to attend to the social nature of knowledge building in order to support the accessing, processing and sharing of information (Brown and Duguid, 2000). Researchers and developers of knowledge building and sharing systems are finding that behavior in these systems is based on more than just the information stores of the systems and the explicit messaging of other members. Behavior is also based on the implicit messaging associated with behavior in these systems, such as being there, choosing actions, and ways of interacting. Researchers of computer supported collaborative environments have identified tacit aspects of communication, such as awareness, co-presence, social navigation, and social proxies, as fundamental to computer-mediated social interaction (Dourish, 2001, Erickson, et al., 2002, Fitzpatrick, et al., 1998). Harrison & Dourish (1996) argue for using the computer (1) as a medium to represent the explicit and tacit information to be shared in a social interaction, and (2) having forms of the medium that are appropriate and effective for the social practices of the "place." Dourish argues that computation is a medium that communicates between social actors and that represents possibilities for action (participation in the world) (Dourish, 2001, Dourish, et al, 1996, Erickson, 1993, Neale, et al., 1998).

Dourish also stresses the notion of "accountability" (making actions observable and reportable) because it provides others with a means to understand and respond to the actions of others for mutually constructed sequences of action. Fitzpatrick et al. (2002) have taken similar notions of accountability in a social space (locale) as a foundation for designing collaborative systems. They note that the integration of functionality to produce, gather and redistribute information from everyday activities with facilities to make the information publicly available and easily accessible enables computer-mediated awareness to support the flow of interaction that happens easily when participants are co-located.

Context-aware Activity Notification System

Based on Strauss's Theory of Action and Vygotsky's Activity Theory, Fitzpatrick (1998) developed the Locales Framework to explain mutual activity in an online environment. Amelung (2005) has extended the Locales Framework by developing a Framework for Notification in online collaborative environments. The implementation of the framework uses a distributed architecture and is called CANS (Context-aware Activity Notification System). The CANS System includes the collaborative online system, such as a course management system, and the CANS Server, which provides communication and database services for notification. CANS supports capturing activity information by establishing a vocabulary of tools and action events, maintaining a history of activity, making notifications available based on the context of use, and allowing users to configure their notification preferences.

CANS works by observing activity in the CMS, such as when a member logs in, reads a discussion board item, uploads a document, or enters a chat message. The records of all these observations are stored in the CANS database and matched with profiles for access to awareness information set by the members. Matches lead CANS to send information to members who want the information in a form they have selected. For example, a student in a group may want to know when the instructor has posted an assignment and have that information immediately emailed or delivered via a desktop widget (a small application that can always be visible on one's desktop). The student may want to see who has posted new messages or read existing messages, but only want that information when they enter the CMS. An instructor may want the same information but want it organized in a table to see who has contributed and how much to a discussion. Thus the awareness information is a resource for instructors and students in knowing when and how to act, and also a tool for an instructor to quickly make sense of what is going on in the course, how to assess what is going on, and identify appropriate next steps for the class or individual students.

CANS Development and Implementation

Over the past 2 years we have developed CANS to work with Sakai. Sakai is a CMS with a community source license that is rapidly emerging as a platform of choice in university environments. As well as being a software system, Sakai is also a community of educators, researchers and developers who are envisioning how software and information systems can substantially improve higher education teaching and learning experiences. The Sakai community, http://sakaiproject.org, includes over 80 institutions of higher education (IHE).

CANS is licensed under the Educational Community License (1.0) version of the open-source license and is designed to work with Sakai or any other network-based application capable of generating or receiving XML. CANS is being used at the University of Missouri-Columbia in online courses and notifications are provided via daily email digests that describe activity within a course context over the past 24 hours. New forms of digests are being developed to show social comparisons and test the influence of various strategies to visualize the activity data. The CANS Server and desktop widgets can be downloaded at http://www.cansaware.com.

FIPSE has funded a three-year project to enhance and extend CANS, test its potential to improve online teaching and learning, and examine the impact of providing more socially attuned course management systems on the acceptance of online learning in higher education. In the first phase of development CANS will be enhanced so as to provide online and customized management of notifications by instructors and students. This ability for customization along with new development to embed notifications within a notifier application on the home pages of course sites will be tested for its impact on the social nature of learning and technology appropriation. Phase 2 will continue the development of phase 1 and add new tools for visualizing course activity as well as integrating notification information into common Sakai tools, such as the discussion board and resources applications. Phase 2 will include testing the impact of notification on teaching practices and learning outcomes, and be undertaken with partners at the University of Michigan and Virginia Tech. In addition the CANS team is eager to find more partners who would like to try CANS and participate in collaborative research to test and extend the potential of activity awareness to improve the social nature of online courses and augment efforts for collaborative learning.

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Virtual Communities of Care: Online Peer Networks with Post-Organ Transplant Youth

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Abstract: This paper discusses the Virtual Communities of Care Project that uses a 3D virtual environment, Zora, to support a psycho-educational intervention for pediatric post-organ transplant patients. These patients have difficulties in developing a peer network due to chronic illness, and as a result they are often incompliant to medical and other requirements. Our goals are to examine the extent to which we can leverage youth interest in technologies to develop an intervention to support peer network building and medical adherence. During an eight-week intervention, participants engage in weekly online group and individual activities in Zora. We describe here the intervention and preliminary data to illustrate the objectives of this project.

Introduction

Virtual environments present an opportunity to promote the positive development of young people and their communities (Barab et al., 2002; Bers, 2006). Such technologies can support the development of youth with life-long medical risk or chronic illness (Bers et al., 2003), who, due to their condition, may not be able to attend school regularly and have difficulty forming peer relationships. In the past, most young people with serious chronic illness, such as those needing organ transplants, would not survive. Today, advances in medicine make it possible to extend the length of their life. However, psycho-social services lag behind medical advances, and youth who benefit from medical treatment still have difficulties adjusting to lifestyle changes and are often incompliant to medical and dietary restriction (Rosina, Crisp, & Steinbeck, 2003). Consequently, they face medical complications despite surgeries and treatment. Rejection to treatment (e.g., organ rejection) is a big problem that these patients are facing.

The goal of this pilot project is to examine the extent to which we can leverage youth's interests in online technologies to create an intervention to improve the overall well-being and health of these young patients. For this research, we developed a psycho-educational program that engages post-transplant youth to participate in Zora, a 3D multi-user environment (Bers, 2001). The goals are to: (1) facilitate peer networking, (2) encourage medical adherence, and (3) support their adjustment to lifestyle changes. This paper provides an overview of this pilot program; discusses the context of this research, the curriculum and technology used; and presents preliminary data.

Theoretical Frameworks

This research is guided by two theoretical frameworks, *Applied Developmental Science* (ADS; Lerner, 2000) and *Constructionism* (Papert, 1999). ADS focuses on the dynamic relations between individuals and contexts. It integrates developmental research with programs and policies that promote positive development by emphasizing the strengths and assets of young people, instead of focusing on preventing risk-taking behaviors. The strengths and assets are categorized into the "Six C's of *Positive Youth Development*" and they include: Competence (cognitive and behavioral skills), Connection (positive relationships), Character (moral centeredness), Confidence (positive self-worth), Caring (empathy), and Contribution (orientation to civic contribute). While most programs conceived within the ADS model have not attended to the role of new technologies in young people's lives or have limited their use to information delivery, this research extends the framework to examine the extent to which networked technologies could support the development of these assets and promote positive development in youth (Bers, 2006).

This research also draws upon Papert's *Constructionism*. Based on Piaget's *Constructivism* (Papert, 1999; Piaget, 1965), constructionism asserts that people learn better when they engage in personally meaningful projects and sharing them with others. Instead of learning as information transmission, it posits that youth can play an active role in their learning and hence promote their development. Thus, the role of technology and learning is to provide the resources necessary to make good choices and engage in behaviors that would lead to learning and development. Drawing from these two frameworks, the guiding principles of this research are to provide the necessary context and tools to assist youth in forming positive social networks and to encourage them in adhering to medical requirements. These aspects of their lives are imperative in ensuring healthy development and overall well-being.

The Virtual Communities of Learning and Care Project

The NSF funded Virtual Communities of Learning and Care (VCLC) Project is a collaboration between a children's hospital in northeast U.S. and our research team. Working closely with physicians and staff at the hospital (including surgeons, psychiatrists, nurses, social workers, and IT staff), we conceive this as a pilot intervention research looking at the use of 3D virtual environments to promote healthy development in pediatric patients.

Hospital physicians referred 22 patients (13 males) between the ages of 11 and 15 for this study. Using a delayed-treatment methodology, the sample is divided into two groups with one group beginning four months before the second. We provide computers and Internet to those without the necessary equipment, and thus no participants are excluded due to a lack of technology. The environment they log onto is a secured one that only participants and coordinators can access. Online activities are recorded by a log system and reviewed daily to ensure safety. The project design includes communication with clinicians if concerns become apparent in regard to participant interactions or other issues indicative of problems in their well-being; however, no such incidence has occurred.

This pilot project uses a virtual environment, Zora, to assist young patients in developing a peer support network and foster medical adherence. Developed as an Identity Construction Environment, Zora provides tools to design and inhibit a virtual city (Bers et al., 2001). Participants populate the virtual city by making interactive creations, including 3D objects, characters, message boards, and signs. Each creation consists of various properties, including a description, value designations and definitions, and narratives to help express meaning and personal stories. Zora also provides a real-time chat for participants to communicate while navigating throughout the virtual world. The environment is designed to provide both synchronous and asynchronous modes of communication in order to accommodate different personalities as well as afford them a chance to self-reflect upon their narratives, values, and stories. This type of self-reflection is an important process in healthy youth development (Eccles, 1999).

Over a period of eight months (or four months for group 2), participants logged onto Zora at any time they wish to explore the virtual city and to populate it with personally meaningful images and objects along with narratives and value designations. Participants also take part in weekly one-hour group activities that range from icebreakers to discussions about dietary requirements and medicines. Group activities are designed to foster collaborations among participants to promote community building in Zora. For example, participants collaboratively built a Halloween house consisting of favorite stories and images from each participant. Other examples include a Zora restaurant, pharmacy, Zora zoo, etc. It is clear from the beginning that, while the virtual environment affords tools for participants to express themselves individually, group activities successfully bring the community together.

Another example is the monthly newsletter, *Transplant Times*, written by participants about their experience. It is printed and distributed to families and physicians as a way to share their experience. This allows participants to collaborate online to create a product that is shared to others outside of the virtual city. Participants choose a monthly theme and topics to write about; they collaborate and share responsibilities such as graphic design, writing, and editing. Through the newsletter, participants share their experience with their family and physicians and it becomes a permanent artifact of their activities. The intention of this newsletter is to illustrate to them that knowledge, relationships, and connections built in Zora can be carried beyond the virtual realm and impact their life.

In addition to building a network, activities are also intended to promote certain assets in participants in hope to increase medical adherence and quality of life. One of Zora's features is that participants are given the tools, not the content, to learn about specific issues (i.e., medical adherence in this case), in ways that are meaningful to them. So instead of planting a "Health Museum" that is dense with information, participants are asked to research about their own or other's transplant stories and build 3D objects and narratives to communicate their ideas and make their own museum. This approach is aligned with the *Constructionist* approach to learning. Finally, physicians and nurses at the hospital periodically attend group sessions to interact with their patients via the Zora system.

Data Collection

Data collection includes three activities. An online log provides qualitative data (activities and coding of 3D creations) and quantitative data (e.g., log-on frequency and number of objects created). Participants completed questionnaires addressing research questions such as changes in coping strategies, medical adherence, the six Cs of Positive Youth Development, and attitudes about technologies. In addition, home-visits are conducted to get a picture of the home context in which they log onto Zora and feedback about their experience.

Preliminary Results

This paper primarily draws on qualitative and descriptive data from the Zora log and anecdotal accounts from Group 1 phase of the study to provide an overview of the project. Participants logged onto the system on average 2.6 hours per week. They took on different roles in the virtual city; some participants tended to decorate and build objects while others focused on sharing stories and chatting. Over the first four months, they created 1,375 objects, ranging from self-portrait pictures to objects representing discussion about health, transplants, and medicine.

The project has been successful in fostering narrative sharing. For example, a participant wrote this story on one of the 3D objects in his virtual house: "I received my liver on [date]. I was only [age] at the time. I received the message while attending a Halloween Party, and me and my family took a jet out to [city]. The donator was a baby girl, named [name], who died of SIDS or sudden infant death syndrome." Besides building Zora creations, participants have also shown interest in the newsletter. Topics have included: featured citizens and houses, tips and tricks for remembering medication, citizens' artwork, and websites for kids. Interview responses have shown that the newsletter is a motivating factor for participants to continue their active participation. For instance, one participant stated, "It was exciting to see my drawings printed. I will do more next time." Physicians and families have also responded positively about the newsletter as a way to get a sense of what participants are doing online. Although we do not experimentally control for the effect of the newsletters, responses have supported our hypothesis that the newsletter helps connect participants' online activities with their real-life experience.

During one-on-one interviews, participants commented positively about the project in regard to their adherence and personal development. In particular, participants discussed how, prior to meeting others in Zora, they felt isolated because other peers "don't really get the seriousness of the matter" and "no one really understands."

Implications and Next Steps

The Virtual Communities of Learning and Care project is a pilot program to examine the extent to which we can leverage youth's interests in technologies to develop interventions to promote positive youth development. This project showed that new technologies can augment psycho-therapeutic services available to post-transplant pediatric patients to help them build stronger peer networks and develop motivation for medical adherence.

Preliminary data, e.g. interview responses and activity logs, identified several components that are central to this project's success. Connecting participants' online experience with real-life (i.e., the newsletter) was critical to our primary objective of motivating them in making positive life decisions (i.e., medical adherence) through their online experience. Future work may look at multi-hospital programs to connect patients from different geographic regions, as well as including patients from different medical units rather than focusing on post transplant patients.

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Learning About Transfer in an Online Problem-Based Course

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Abstract: Problem-based learning (PBL) is an instructional method in which students collaboratively learn through problem-solving. Students solve a complex problem, direct their own learning, and reflect on their learning. In a STELLAR course, PBL was adapted for an online CSCL environment for preservice teachers. The study demonstrates that students who participated in a STELLAR course learned more about transfer than students in a traditional course.

Problem-based learning (PBL) is a methodology for student-centered learning that relies on small, facilitated, collaborative groups (Barrows, 1996). In PBL, students learn through solving complex problems and reflecting on their experiences. As students work on a problem, they identify what they need to know in order to solve a problem and engage in self-directed learning to address those needs. The facilitator acts to guide the learning process, helping to promote the development of knowledge and reasoning strategies as well as promoting self-regulated learning. PBL curricula have had positive effects in promoting learning and transfer, particularly in medical education (Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hmelo, 1998). The STELLAR (Socio-Technical Environment for Learning and Learning-Activity Research) system adapts the PBL model to specifically support preservice teachers in gaining an understanding of Educational Psychology that they can transfer to their classroom practice. PBL should promote effective transfer because students repeatedly bring together conceptual ideas underlying a domain with visions and plans of professional practice as they construct what we call a meshed schema representation (Derry, 2006; Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006).

STELLAR is an online PBL environment that enables preservice teachers to engage with Educational Psychology concepts by using video cases as contexts for collaborative lesson redesign. The system consists of three components: an online Educational Psychology hypertextbook (the Knowledge Web); a PBL online module; and a library of video cases that present examples of classroom practice. These cases provide rich contexts that present opportunities for discussion as students engage in redesign of instruction depicted in the cases as well as providing links to the Knowledge Web, helping students identify fruitful learning issues. The PBL online module includes tools that provide a loose script as they scaffold students' individual and group PBL activities (Dillenbourg, 2002). These include a personal notebook where students record initial observations, a threaded discussion, where students share research, and a whiteboard where students discuss proposals for lesson redesigns. These tools embody an instructional planning process based on the backwards design model of Wiggins and McTighe (1998).

STELLAR courses consist of 3-4 problems each lasting 2-3 weeks using a hybrid online and face-to-face course structure. The asynchronous discussions promote reflection and allow a facilitator to work with multiple groups. We integrated domain-specific scaffolding to support principled instructional design activities and help structure the collaborative PBL process. The students' goal is to redesign a lesson based on Educational Psychology principles. They begin by individually studying a video case (STEP 1). In STEP 2, they record observations and brief individual redesign proposals in an online personal notebook that guides students towards lesson features relevant for redesign. This work is shared with group members in STEP 3. The group identifies concepts they need to explore for redesign (STEP 4), conducts and shares research (STEP 5), and collaboratively designs lessons (STEP 6). They use threaded discussions and a group whiteboard as shared workspaces in steps 4-6. The redesign is shared at a poster session. The students meet face-to-face for STEP 4 and again as they present solutions at the completion of STEP 6. Students provide individual explanations of the group proposal in STEP 7 and reflections in STEP 8.

In previous research, we have demonstrated that students who have participated in STELLAR courses demonstrate improved understanding on targeted learning outcomes (Derry et al., 2006). The earlier results demonstrated that students who participated in a STELLAR course learned more about the concept of understanding than a comparison group. The goal of the current study is to examine whether other targeted outcomes were achieved, in this case, whether students learned about the concept of transfer.

The purpose of the current research was to examine 1) students' acquisition of knowledge about the concept and principles of transfer and 2) their ability to generate ideas about instructional methods that would facilitate transfer and the learning process. It was hoped that the questions the participants answered would capture their knowledge along the three dimensions as defined by Sugrue (1995): concepts, the principles that link concepts, and the conditions and procedures under which concepts and principles should be applied. The hypothesis underlying the research was that students in a PBL class would outperform students in a traditional class in both their knowledge acquisition and application of that knowledge.

Methods

Seventy preservice teachers taking Educational Psychology classes in a state university in the northeast United States participated in the research. Thirty-three participants were taught Educational Psychology in the PBL class. The remaining thirty-seven participants were drawn from the Educational Psychology subject pool and received course credit for their participation. The PBL class was organized around five themes: the constructive nature of knowledge (understanding), the social nature of learning, transfer, motivation, and feedback and revision. The STELLAR participants had access to the STELLAR environment described above. They were required to work in groups to discuss their understanding of material and construct group learning artifacts. The groups were formed to be heterogeneous with respect to the different planned teaching specialties. The comparison classes used standard textbooks. Participants in the traditional classes met face-to-face and participated in lectures and other activities that their course instructors deemed appropriate.

Participants viewed a brief video in which high school students learned about electricity, electrical circuits, and how a light bulb works. Before viewing the video, they received a brief written explanation describing how the video clip illustrated a problem the teacher had identified in his teaching. The video explained how the teacher had spent a month covering advanced topics in electricity and provided hands-on experience designed to reinforce those concepts and illustrate how electricity enabled a light bulb to work. The video also showed an interview with a student before and after instruction and demonstrated that she maintained the same misconceptions following instruction. After viewing the video, the participants in both the traditional and STELLAR classes were given pretest questions. They had thirty minutes to answer the following four questions: 1) How do you know that the student failed to learn?, 2) Why did the student fail to learn?, 3) What recommendations would you make to help him improve his teaching?, and 4) What else do you need to know to better understand the teaching-learning situation? What additional questions would you ask? At the end of the semester, the participants in both the traditional and STELLAR classes completed an identical posttest.

On the pre- and post-tests, a rubric on the concept of transfer was used to evaluate participants' responses, and then a rating between 0 and 3 was assigned to the participants' overall responses. The transfer rubric included several features of transfer that participants could use to discuss the video including the fact that transfer: 1) requires understanding, 2) involves activating appropriate prior knowledge and applying something learned in a new situation, 3) involves abstraction and cognitive flexibility, 4) can be near or far transfer, and 5) can be preparation for future learning. The ratings were based on the degree to which the participants included and elaborated upon these features of transfer in their written answers to the four questions noted above. The ratings indicated progressively greater understanding of the concept of transfer and its application. Answers that received a level 0 rating indicated that there was no evidence that the target concept was understood. A level 1 rating indicated incomplete understanding and a lack of causal explanation or application of concepts. A level 2 rating showed greater understanding and elaboration. A level 3 rating showed sophisticated understanding, with explanations that showed cause and connections to other frameworks. This was adapted from the rubric for the concept "understanding" used in Derry et al. (2006). Participants' written responses were scored blind to condition. Two independent raters scored 30% of the data and had interrater reliability of 83.33%. Disagreements were resolved through discussion.

Results

Means and standard deviations for both classes are shown in Table 1. A 2x2 mixed ANOVA was conducted using time as a within subject factor and class as the between subject factor (STELLAR vs. Traditional). The results of the ANOVA showed a significant class x time interaction, F (1, 68) = 106.18, p <. 001. Simple effects tests showed a significant change over time for the PBL class (t (32)=12.79, p<.001) but not for the traditional class (t(36)=1, p=.32).

Table 1: Pretest and Posttest Means and Standard Deviations

Type of Class	N	Pretest	Posttest
STELLAR	33	0.71 (0.31)	2.02 (0.69)
Traditional	37	0.61 (0.36)	0.68 (0.34)

Conclusions

The results of this research indicate that students who participated in the STELLAR course constructed a deeper understanding of the concept of transfer and were able to apply their understanding of the concept to generate recommendations for improvements of instructional methods. This evidence helps provides generality to the results of Derry et al. (in press), which demonstrated similar results for another targeted concept.

The STELLAR approach represents an example of a problem-based approach to CSCL. These results suggest that 1) problem-based approaches can foster deep learning and 2) an integrated CSCL system can be used for PBL. Further research is needed to examine the impact of student interaction with different aspects of the STELLAR system, with each other, and with the facilitator.

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Acknowledgments

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Just a cog in the machine: participatory robotics as a tool for understanding collaborative learning and decision-making

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Abstract: We will demonstrate the integration of a software-based multi-agent modeling platform with a participatory simulation environment and a real-time control system for a physical robotic agent. Both real and virtual participants will be able to act collaboratively in a simulation that will control a physical agent. The backbone of this demonstration is a widely used, freely available, mature modeling platform (NetLogo). We posit that this technological platform can be of use for researchers interested in investigating collaborative learning and decision-making, as well as to design collaborative learning activities. We will present preliminary findings from pilot studies with the tool.

Introduction

Agent-based modeling has been increasingly used by scientists to study a wide range of phenomena such as the interactions of species in an ecosystem, the collisions of molecules in a chemical reaction, and the food-gathering behavior of insects (Bonabeau, 1999; Wilensky & Reisman, 2006). Such phenomena, in which the elements within the system (e.g., predators, molecules, or ants) have multiple behaviors and a large range of interaction patterns, have been termed *complex* and are collectively studied in a relatively young interdisciplinary field called *complex systems* (Holland, 1995). Typical of complex phenomena is that the cumulative (aggregate) patterns or behaviors at the macro level are not premeditated or directly actuated by any of the lower-level, micro-elements. For example, flocking birds do not intend to construct an arrow-shaped structure (Figure 1), or molecules in a gas are not aware of the Maxwell-Boltzmann distribution. Rather, each element (agent) follows its "local" rules, and the overall pattern arises as epiphenomenal to these multiple local behaviors i.e., the overall pattern *emerges*. In the late eighties and early-nineties, Wilensky & Resnick (1993, 1995) realized that agent-based modeling could have a significant impact on learning. They adapted languages and techniques heretofore used only with supercomputers and brought them to classrooms. Powerful ideas such as emergence, self-organization, and randomness were put in the hands (and minds) of children. To study the behavior of a chemical reaction, the student would observe and articulate *only* the behavior of individual molecules — the chemical reaction emerges from the interactions of these molecular agents. Once the modeler assigns agents their local, micro-rules, the system can be set them into motion and modelers can watch the overall patterns that emerge.

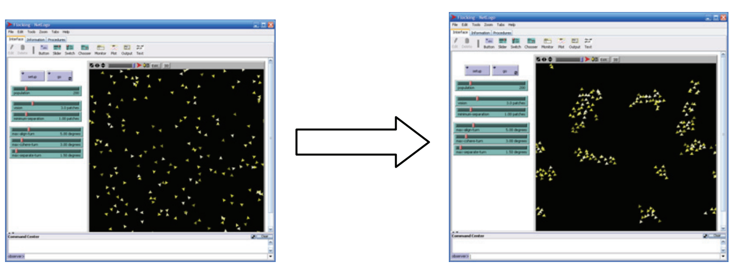

Figure 1. An agent-based model of the flocking behavior of birds.

Participatory simulations are similar to multi-agent simulation except that students play the role of the virtual agents, sometimes in combination with the virtual agents (Wilensky & Stroup, 2002a). In a typical participatory simulation, a server runs a computer model, and students connect to the server through a networked computer or calculator. The behavior of the whole system is not defined ahead of time but instead emerges from the participation of various individuals in the simulation. This emergent behavior can then be displayed to the participants through a central server with the results usually projected at the front of the room. Each of the participants will be assigned one agent on the screen, and would control its behavior. For example, in the traffic "Gridlock" (Wilensky & Stroup, 2002b) participatory simulation activity (PSA, Figure 2), each student controls a traffic light in a busy city. In the "Disease Spread" PSA (Wilensky & Stroup, 2002b), each student will be assigned different roles (doctors or patients).

We have also recently started to incorporate physical devices in agent-based models, using sensors and probes to gather data about the real-world phenomena under scrutiny. The presence of physical sensors enables students to ground their models in empirical data and further refine the models. This approach, *bifocal modeling*, permits a deeper understanding of the physical world than pure virtual modeling (Blikstein & Wilensky, 2006). This is particularly true within educational robotics, where research has shown that designing and controlling devices in the physical world introduces new challenges such as understanding error, noise, mechanical advantage, and mechanical failure, which cannot be explored in purely virtual environments (Martin, 1996).

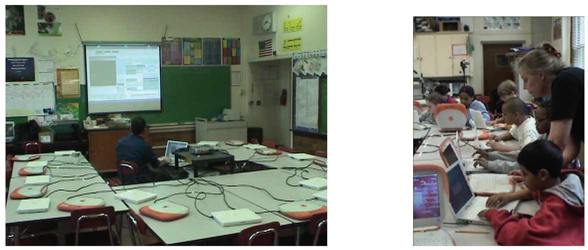

Figure 2. A classroom ready for a participatory simulation (left), and students during the activity (right)

Rationale and technological design

The three aforementioned areas (agent-based modeling, participatory simulations, and bifocal modeling) are concerned with the creation, manipulation, and development of agents in one form or another. Thus combining these three systems in to one unified platform would be useful, since it would facilitate a synthesis of their main affordances: understanding of the role of locality and emergence (agent-based modeling), mapping human action to emergent, collective behaviors (participatory simulation), and controlling physical objects in noisy environments. We will demonstrate a novel technological based on the NetLogo/HubNet (Wilensky, 1999) architecture that supports simulated agents, participatory agents and physical agents. We have developed a methodological framework to help us understand this system, the "Human, Embedded, Virtual agents via Mediation (HEV-M)" framework (Rand, Blikstein, & Wilensky, 2006). Within this framework and the accompanying platform, designers can create participatory simulations in which each participant controls one element within a physical system (a car, a mini-factory, a robotic arm with multiple joints, etc). In the conference, we will show one instantiation of the platform (see Figure 3). It consists of a robot-car with four motors. Each motor is connected to a serial interface board (the GoGo Board), which communicates to the server. Each of the four users is assigned a motor to control, and turning the car is achieved by reversing the correct pair of wheels on each side of the car.

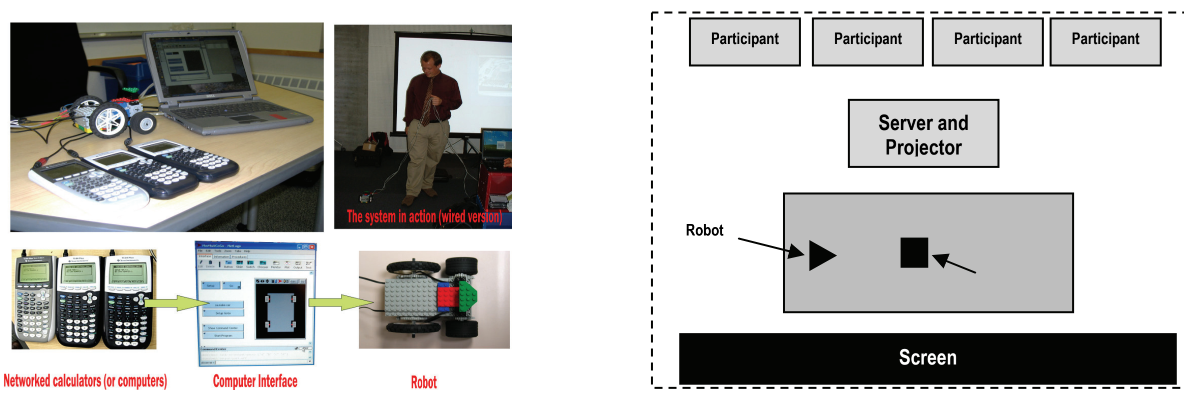

Figure 3. The system's components (left), and the schematic setup of the demonstration (right)

Preliminary User Studies

We have run three preliminary studies, two of them at professional conferences for computer scientists, and one at a research university with doctoral students and faculty. The setup was identical in every situation. The apparatus was setup on the floor (see Figure 3), and there were four notebook computers placed in front of the robot car. Each of the four participants could turn the motor on and off, reverse direction, and change the motor power level. They were given the simple task of moving the robot forward while avoiding an obstacle along the way. As these were proof-of-concept studies, our evidence is based on observations of the activity. At this stage of the development of our platform, the studies were exploratory, both to provide initial insight into participants' reactions and to improve our design. Nonetheless, the results were intriguing. Before the start of the activity, participants were very confident that they could accomplish the task with ease. However, as soon as the first turn of the robot was necessary, participants would start talking back and forth, asking who had control over which wheel, and which state (forward, backward, high power, low power) each wheel was in. At this point, participants started to report increasing frustration with their ability to solve the problem, and started complaining that the other participants were not helping them. In two of the groups, we observed some emergent strategies for optimizing the process, such as delegating leadership to one participant, or the formation of two groups each with two participants, which would then act fairly independently. In the end, the three groups were able to reach their goal, but often it took much longer than they expected, and several of them got stuck for long periods of time right around the obstacle. These preliminary runs of the platform seem to indicate that there were two levels of learning taking place. At the individual level, participants were trying to learn how to better control their own wheel. At the group level we saw evidence of strategy-generation, especially as participants appeared to learn that individual actions and groups actions are fundamentally different. For example, at the onset of the activity, they were unaware that an error from *any* of the participants would ruin the group's goal, no matter how well the other participants were doing. From our observations and interviews, it was noticeable that the "hands-on" experience in the participatory task challenged the initial strategies, and many participants claimed that they would use a different strategy if attempting the task again.

Conclusion

We have built a technological platform for investigating collaborative learning and decision making. Our platform seamlessly integrates three technologies: agent-based modeling, educational robotics, and participatory simulations. We believe that this tool has significant potential for three main reasons (1) it enables logging of participant's actions, as to identify patterns and match them to observations, (2) it offers researchers in the field of computer-supported collaborative learning an easy to-use tool to design engaging collaborative learning activities and, (3) it foregrounds the role of individual actions within the accomplishment of a collective goal, highlighting the connections between simple individual actions and the resultant macroscopic behaviors of the system.

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Why Technology Isn't Making a Difference: Coming to Terms with Ubiquitous Learning in High School Classrooms

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Abstract: This qualitative study investigated teachers' and students' participation in a 1-to-1 laptop initiative. The study explored how high school teachers' beliefs about technology and education impacted classroom instruction. Findings revealed how teachers' conceptions of English education and their predominantly logocentric view of language reinforced individualized instruction and a transmissive model of education. Findings alert educators to the views and beliefs of technology integration that can undermine collaborative and transformational uses of technology.

The advent of the Internet and various forms of information and communication technologies (ICT) have created an information-age which is redefining what it means to be literate in today's society. From cell phones, email messages and digital libraries to online banking, technology is playing an increasingly significant role in our lives (Leu et al., 2004). As technology presents new possibilities for communicating and accessing information, the literacy practices in which people make meaning, communicate, and express themselves are continually evolving (Leu et al., 2004). Now, perhaps more than ever before in the history of adolescent literacy education, the "demands of new technologies and the complexities of living in a highly globalized society" are seriously taxing educators' capacities as a profession to respond to adolescents' needs in ways that "will enable them to become fully functioning citizens of the 21st century" (Alvermann, 2000, para. 4). In response to today's Digital Society and a need to prepare students for the literacies that are becoming central for accessing, acquiring, and critically analyzing information, local, state, and federal initiatives have been created to assist teachers to effectively integrate technology to support student learning (NCATE, 2006). In an effort to support preservice and practicing teachers in meeting these initiatives, teacher educators are faced with new challenges to "prepare graduates who are capable and committed to using technology as a learning tool" (Howland & Wedman, 2004, p. 240). These challenges, however, are occurring at a time when far too little research exists on these literacies and the ways in which both teachers and students acquire the skills that are essential to succeed in today's information-rich world (Leu et al., 2004). A number of researchers have found that technology is frequently underused, poorly integrated into classrooms, and seldom impacts or alters teachers' regular teaching practice (Cuban, 2001; Hennessey et al., 2005). In addition, Goodson and Mangan (1995) have argued that relatively few teachers are integrating new technologies into subject teaching in a way that "motivates pupils and enriches learning or stimulates higher-level thinking and reasoning" (p. 14). The purpose of this study was to investigate how technology was used in ninth and tenth grade classrooms where all teachers and students had access to their own wireless, laptop computers. The research questions guiding the study were a) How do high school English teachers, during their second year of the laptop initiative, use technology to support teaching and learning? and b) How do teachers' beliefs about the role of technology provide insight into the ways in which technology was being used?

Related Literature

A number of researchers have described how technology is often underused and poorly integrated into classroom practice (Cuban, 2001; Goodson & Mangan, 1995; Hennessy et al., 2005). Some researchers have argued that encouraging changes in teachers' instructional practices and their beliefs toward technology integration can present more of an obstacle to technology integration than having limited resources (Rogers, 2002). Studies have revealed that the process of changing teachers' pedagogical thinking can be quite slow, and there is still much to learn about how to support teachers in making these changes (Borko & Putnam, 1996; Kerr, 1991). Lagrange et al. (2001) have argued that the predominant focus of most current research has focused on the difficulties that students confront when learning with ICT and not on teacher learning. In an effort to further explore teacher learning and beliefs in relation to technology and education, the researcher designed the current study with the belief that knowledge is socially constructed. She also designed the study believing that literacy learning is ultimately multimodal in nature. A multimodal approach to learning requires educators "to take seriously and attend to the whole range of modes involved in representation and communication" (Jewitt & Kress, 2003, p. 1). When viewing technology integration from a multimodal perspective, the meanings of words and images, "read or heard, seen static or changing, are different because of the contexts in which they appear -- contexts that consist significantly of the other media components" (Lemke, 1998, para. 2). A multimodal view recognizes how "written-linguistic modes of meaning are part and parcel of visual, audio, and spatial patterns of meaning" (Cope & Kalantzis, 2000, p. 5). According to Lemke (1998), current theories and teaching of literacy "have been long been too logocentric," where language alone is seen "as a reliable medium for logical thought," and where written language is perceived "as the primary medium of, first, authoritative knowledge, and lately of all higher cognitive capacities" (para. 3).

Methodology

Both deductive and inductive analyses were used for qualitative data following grounded theory and constant comparative methods (Glaser & Strauss, 1965). The study followed teachers and students who participated in a district-wide, one-to-one laptop initiative where all teachers and students received wireless, laptop computers. The study began at the beginning of the school year when the district was entering its second year of the laptop program. The researcher documented how six high school English teachers integrated technology into their classroom instruction and how students responded to the use of laptop computers in their classes. The researcher conducted 59 classroom visits and interviewed each teacher and 10 focus students. In addition, she collected descriptions of class assignments and invited each teacher and over 120 students to complete two online surveys. All interviews were audio recorded and transcribed. During analysis, the researcher noted common patterns and inconsistencies in responses. She noted and coded all information that directly related to research questions and that revealed teachers' views of literacy learning and technology integration. When patterns emerged during analysis, the researcher revisited and coded data that had been collected to see if they confirmed initial findings. When patterns of responses appeared to be supported with more than one example and by more than one participant, the researcher noted this and continued to analyze and code for these patterns. Using the software program *Nvivo*, she periodically searched through data to see if new codes supported initial findings. This searching, rereading, and coding process continued until no new codes emerged.

Findings

Although teachers had various opportunities to participate in technology workshops, were involved in the laptop initiative for over a year, and were supported by administrators who wanted a stronger emphasis on problem-based learning, findings revealed that teachers' predominant uses of technology were to organize information for the sake of efficiency and to use the Internet for information seeking purposes. During class, students used technology for both academic (e.g., taking notes, giving presentations) and personal (e.g., viewing music videos, writing instant messages to friends) reasons. Although the level of integration varied across classrooms, the majority of observed instructional practices continued to reflect the typical I-R-E (initiation, response, evaluation) pattern and teacher-led discussions that are common in many high school English classrooms (Applebee et al., 2003). Findings related to teachers' conceptions of English instruction and technology help shed light as to why their pedagogical practices did not change. Findings also reflected how teachers struggled to see how technology could play a role in enhancing student learning and English instruction. Despite a district-wide, professional development focus on technology integration, teachers' views of literacy learning and ways of knowing appeared to remain very "logocentric," placing an emphasis on how meaning is made through language and text (Lemke, 1998). Teachers' perceptions of technology integration and their subject matter reinforced these views and often resulted in a use of technology that mirrored their usual, ongoing classroom practices. For example, one teacher clearly stated her views when she commented how English class consisted of mostly "reading, writing, and discussing." She then stated that she believed technology did not play a "prominent role" in the English classroom. When comparing students' engagement during class, a second teacher's views of English education and technology were revealed. He described how "there are still plenty of students who just love to write with a pen. And those are the students that will become English majors probably." A third teacher's revealing comments were made when she described the process of teaching students to write essays and conduct research. She explained how students had to first learn the "traditional" way and "imitate first, innovate later." She added, "Then you can play with technology, but first you have to do it the proper way. First you have to do it with slates and chalk then you can get into all the other stuff." She then added, "It doesn't enter my mind that it can be done the right way with technology the first time." When a fourth teacher described her views about technology and the research process, she described how laptops were used more for "individual research and development" rather than for collaborative and group work. All teachers' comments supported and reinforced the limited use of technology that was observed in each classroom.

Conclusion

Research has revealed that instead of actively engaging students in practices that support literacy learning, the typical pattern of instruction found in high school classrooms is teacher-centered and places a heavy emphasis on the transmission of information. Applebee and his colleagues (2003) have argued that such patterns of classroom instruction actually hinder rather than help the education of students. Viewed from a sociocognitive perspective, this type of instruction provides "very little room for the exploration of ideas, which is necessary for the development of deeper understanding" (Applebee et al., 2003, p. 689). This study revealed how specific views and beliefs about technology and English education might limit teachers' efforts or desires to use technology in more innovative and collaborative ways. The study provides additional insight into the challenges and complexities that surround technology integration. It also highlights areas of research that need to be further investigated if teacher educators, researchers, and administrators hope to promote change in teachers' classroom instruction. As researchers continue to explore the various ways in which technology can facilitate knowledge-building in collaborative spaces, they should also explore effective ways for conveying this knowledge to classroom teachers. As new information is shared, researchers should also look closely at the ways in which teacher education and professional development programs are (or are not) impacting individual's views of technology integration and their conceptions of subject matter learning.

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Interaction Analysis in Asynchronous Discussions: Lessons learned on the learners' perspective, using the DIAS system

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Abstract: DIAS is an Asynchronous Discussion Forum Software, developed in order to offer extended monitoring and interaction analysis support, by providing a wide range of Interaction Analysis (IA) indicators jointly used in various situations, to all possible users (individual students, groups, teachers/moderators, researchers/observers), appropriate for their various roles in different activities. In this paper we present a brief overview of the research and results regarding the students as IA tool users, deriving from four conducted studies, in educational contexts.

Introduction

Asynchronous discussion forae are nowadays widely used in formal or informal educational contexts, applying principles of constructivism, emphasizing in social interaction during learning activities. Research is focusing towards finding methods for supporting critical thinking through interactions, occurring within asynchronous discussions, in order to achieve high quality learning. Such a goal requires tools, frameworks and methods for the facilitation of monitoring and/or self-reflection and therefore selfregulation that could be supported by the automated analysis of the complex interactions that occur. D.I.A.S. is a forum platform with integrated Interaction Analysis (IA) tools. In the current paper, we present a general overview of the research questions and results, focusing on one of the perspectives: this of adult learners (students) as IA indicators' users.

Theoretical Background

Critical Thinking is an intellectual process allowing learners to construct new knowledge through problem solving and collaboration. While implementing discourse activities by means of discussion forae, higher levels of interaction are needed to encourage learners to think critically, as indicated throughout the literature (Henri, 1992; Gunawardena et al, 1997; Garisson et al, 2001), along with internal reflection. It is often necessary for the learner to externalize his/her thoughts in order to achieve proper reflection, thus promoting message writing in discussion forae as an ideal reflective process. Intensive discussion and social interaction may lead to multiple knowledge construction phases (Schellens & Valcke, 2005). Our main research axis is peer support in asynchronous discussion learning activities, in order to trigger metacognition, which leads to selfregulation, as well as to facilitate the moderator's tasks. Our intention is to build tools by applying Interaction Analysis techniques in discussions' activity data, visualizing and providing quantitative information directly to technology-based activities' participants, in order to self assess their activity (Dimitracopoulou et al, 2005; Dimitracopoulou & Bruillard, in press). The IA results are presented in an appropriate format (graphical, numerical, literal), interpretable by the users, providing an insight of their own current or previous activity allowing them to reflect on a cognitive or metacognitive level, and thus act in order to self-regulate their activities. Additionally, IA provides information to the activity observers, in order to analyse the complex cognitive and social phenomena that may occur. The expected outcome is the optimization of the activity through: a) better activity design, regulation, coordination and evaluation by the forum moderator, and b) refined participation and learning outcome for the students through reflection, self-assessment and self-regulation.

The Discussion Interaction Analysis System (DIAS)

While examining Forum and Forum Type software, we found several drawbacks in participants' support. These include minimum analysis information provision, information provided only to a portion of the participants (e.g. the teachers), closed and/or complex, non-transparent analysis systems or even lack of empirical research (Bratitsis & Dimitracopoulou, 2006). This led us to the development of the DIAS system, a fully functional discussion forum platform. We took into account that users involved in a 'learning activity' form various cognitive systems, as individuals (students and teachers in various roles) or members of groups or even communities, thus expressing different needs for support. Different indicators' sets are addressed to students, teachers, moderators (the latter having increased information needs while monitoring, assessing, evaluating), or researchers along with the corresponding *Interpretation Schema* for various discussion strategies or usage scenarios. An *Interpretation Schema* explains how to combine different indicators, in order to extract additional, more qualitative information. All the indicators are produced by measuring quantitative activity data. The implemented charts vary from having low (presenting very simple and understandable information) to high interpretative value (providing several aspects of information, which can be different, depending on the type of user who is reading the indicator). Finally, customizability, flexibility and interoperability are considered to be crucial characteristics for independent analysis tools, such as DIAS. More related information can be found in Bratitsis & Dimitracopoulou (2006; in press).

Research Results' Overview

Four case studies implementing a different educational activity approach have been designed *in situ*, constituting the core teaching method for the corresponding semester courses. Similar data collection and analysis methods were used, including questionnaires, experimental (allowed to review IA indicators) and control groups (not reviewing indicators) monitoring and semi-structured interviews with every participant. Some of the questions asked aimed at: (a) *Detecting the most/least popular indicators and the latent reasons*, (b) *Detecting and explain user behavior alterations due to the indicators' presence*, (c) *Measure the frequency of reviewing the indicators*, and (d) *Distinguishing users' information preference* (individual or group data, personal or related to others' actions?). During interviews, *all the system's indicators* were reviewed and discussed upon, in order to examine their transparency. Additionally we intended to record utilization ideas and initial reactions to the indicators' information – "*What do you understand by observing this diagram*?", "*Would this affect you and in what way*?", "*Do you think this information is important and why*?". The most powerful indicators in matters of explanatory value were correlated with the discussions' actual content, in order to examine possible relations.

Examining the "*influence of IA indicators on the users*", we came to the concrete conclusion that they operate as a very powerful motive for participation. Users being positively surprised by the dynamics of the presented information were very enthusiastic and eager to use the IA indicators during the discussion activity (94 out of 98 agree). Regarding "*how often did the users review the indicators*", almost 60% did so every time they connected and 80% at least 2-3 times per week. Researching the "*kind of information users were interested in*", 70% of them preferred comparative information, in order to assess their actions in regard to those of their collaborators. Individual indicators were less preferred (50% of the users), mostly for confirming their impression of their personal activity. Another important issue for the IA field is "*how users decode visualizations*". Apparently, that most of the indicators were adequately transparent. Using simple diagrams, such as bar-charts, XY-charts and scattered charts facilitates understanding, since everybody is familiar with them. A careful choice of colors may be an additional facility. For example, a gradient transition from blue to red color in the background of the *Classification Indicator* (Bratitsis & Dimitracopoulou, 2006) indicates the desired area for a user to be placed upon. Additionally, through the interviews, we decided that instructions are necessary in order to better utilize the IA indicators. In some cases, users understood the main concept of a diagram, but were unable to "read between the lines", detecting more refined information. Furthermore, combinations of different indicators, in the form of an *Interpretative Schemas*, should also be provided, as it is difficult for a simple user to think of all the possibilities, regardless of his/her role.

Another, equally significant issue is "*how the indicators affect the users and the learning process at extension*. *Do they help users develop their selfregulation processes? Do they help monitor and assess dialogic activities?*" Apart from functioning as a strong participation motive, which one could ascribe to the users' sensation of being monitored by the teacher, results of further analysis of users' actions were very encouraging. For example, postgraduate students who understood SNA diagrams were tighter connected with their collaborators, than just reading and writing more messages (in some cases at the expense of content quality). They tried to truly interact with more collaborators, which resulted in more profitable conversations. Another example is the effect of the Tree Structure indicator (Bratitsis & Dimitracopoulou, in press), which shows the number of threads within a discussion forum that an individual user has participated in. Students reviewing this indicator participated in more threads than those who didn't. These simple examples lead to the conclusion that IA indicators *do affect users and the learning process at extension*. Their effort to improve their interaction status within the discussion activity consequently increased the prerequisites for high order thinking and learning. Higher interaction facilitates critical thinking and sustains effective discussions (Palloff & Pratt, 1999; Garisson et al, 2001; Schellens & Valcke, 2005). In matters of "*facilitating understanding and assessment of discussions activities' goals*", the indicators helped students to evaluate their participation and see if they respected the discussion and the collaborative process. For example, in a multiple phase activity, some students admitted that various group activity indicators assisted them in better noticing increased activity periods, thus distinguishing the emerged course phases. In that manner, they assisted them in understanding the effective activity planning and indicated how and when they should act. More ideas generated by students (while using the indicators on their behalf) clearly showed that specific indicators improve monitoring of the process and better assessment of the current situation.

Discussion – Future Work

Our main conclusion is that the use of IA indicators in asynchronous discussions is an engaging and efficient approach. The overall impression was very positive and we were able to observe shifting in users' behavior, as they appeared more active and productive. Some indicators were more preferred than others, regardless of the teaching settings, whereas some of them are better utilized under specific context and activity settings. For example *SNA diagrams* seem more appropriate when heavy interaction among smaller groups is pursued, whereas *Activity Indicators* (Bratitsis & Dimitracopoulou, 2006; in press) seem more appropriate in cases of open ended discussions with a large number of participants. We consider that a large number of case studies are necessary in order to extract concrete results for that matter. The complexity of the IA process evaluation and the variety of the produced diagrams, indicate that this method is useful for medium and large-sized groups of students, as it is easier to review the actual messages for groups of less than 5 or 6 people. Having produced several *Interpretative Schemas*, which were positively evaluated by the participants (Bratitsis & Dimitracopoulou, 2006; in press), we were very surprised to see that users came up with new ideas for utilizing indicators. New indicators were built in the process, as new needs were expressed. This seems to be a perpetual process, which may lead to the creation of an "Idea Repository". Detailed instructions are required, if we wish users to exploit the indicators. Otherwise, the produced diagrams would seem like an additional workload, with no clear meaning. Consequently, users would avoid taking them into account

Future plans include conducting additional case studies, in order to explore further aspects of the IA perspective. Results found under specific learning settings, should be tested for validity under different settings (for example using a different collaborative learning strategy). Furthermore, new questions arose. Does age influence the users' perception and decoding of visualized information? Do indicators presenting similar information with different visualizations affect users in a different way? If yes, when should each approach be used? For example, some indicators present comparative activity information using absolute values and others use percentages. Thus, the gaps within the charts appear larger in the first case. Could this be a reluctant factor for a less active user, assuming that bigger effort is needed in order to improve his/her position? On the other hand, could this affect likewise more active users, leading them to reduce contributions? Would using smaller gaps affect user motivation? The variety of new questions is quite big, but all of them relate to research refinement of the indicators' effect on the users individually, as a group or a community and the learning process. The overall conclusion that applying IA methods for building tools to support the participants of an asynchronous discussion activity is one step at the right direction, should be the main lesson learned from this approach.

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Supporting controversial CSCL discussions with augmented group awareness tools

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Abstract: An experimental study investigated the influence of an augmented group awareness tool on controversial online discussions and decisions made by 4-person learner groups. The study employed an informed minority paradigm where one group member holds a correct viewpoint, but is faced with a 3-person majority holding an incorrect viewpoint. Within this paradigm, groups using an augmented group awareness tool based on learner ratings of agreement and novelty of contributions were compared to groups using a standard online discussion tool. It was shown that majority influence occurred in unsupported groups, whereas augmented group awareness tools strengthened minority influence, as indicated by group decisions and individual correctness of decisions.

Introduction

Since the early 1990s the notion of awareness has figured quite prominently within the field of CSCW (computer-supported cooperative work). The concept of awareness is rather vague, but there is some agreement that it refers to the perception and knowledge of contextual variables about the material and social world that surrounds a person or a group (Endsley, 1995). This paper seeks to empirically explore the question whether the concept of awareness can be fruitfully adapted and applied to the field of computer-supported collaborative learning (CSCL).

There is a huge diversity of how the term awareness is employed in the literature, and several attempts have been made to categorize this field (e.g. Carroll, Neale, Isenhour, Rosson & McCrickard; 2003; Christiansen & Maglaughlin; 2003; Gross, Stary & Totter, 2005). For the purpose of this paper it is sufficient to state that we make a distinction between situational awareness (knowledge and perception about the material environment surrounding a person) and group awareness (knowledge and perception about the social environment surrounding a person). This paper involves an inquiry into group awareness, i.e. knowledge and perception about the presence, the activities, and the products of other persons in a collaborative setting.

Group Awareness

Group awareness is comprised of several elements, among them knowledge and perception of who is there, where other persons are located, where they are looking at, and what they are doing (Gutwin & Greenberg, 2002). It is evident that group awareness is easily available in face-to-face (FTF) scenarios. However, once group members are spatially separated, group awareness has to be facilitated by means of technological support. Consequently, the use of group awareness technologies has become widespread in digital environments, ranging from lists of active users in online discussion forums (who is there) over avatar embodiments in virtual environments (where are they located, where are they looking at) to video screens, shared scroll-bars in collaborative editors, activity indicators, timelines, and other widgets used in shared workspaces (what are they doing).

Against this background our own research on group awareness and development of group awareness tools departs in two directions. Our first extension of group awareness refers to the type of information that participants receive about their group. Group awareness is a natural by-product of FTF interaction. Consequently, many CSCW approaches try to re-establish FTF conditions by technological means. Most examples of group awareness tools refer to information about the group and its members that would be easily available in FTF settings (e.g. seeing who is there, seeing what others are doing). While providing FTF-like conditions by technological means is a legitimate goal for systems designers, we would argue that the true power of technological support can be shown only if technologies give rise to kinds of interaction that actually surpass FTF levels to some degree. The focus of our own research therefore is on augmented group awareness tools that provide information that would be difficult or impossible to yield in FTF interaction. More specifically, our tools are designed to provide information about entities having no physical equivalent, e.g. on non-observable psychological constructs like knowledge, attention, attitudes, preferences, or emotions.

The principle of augmentation is far from novel. Therefore, our own research draws heavily from work in the field of social navigation (Höök, Munro & Benyon, 2002). Social navigation describes the various influences that the visualization and feedback about other users' behavior has on the navigational behavior of an individual. Many forms of social navigation focus on so-called recommender systems where an individual's choices are informed by recommendations of other persons. Social navigation can either be direct (i.e. users explicitly rate certain items which leads to recommendations for other users), or it can be indirect where the online navigation of users will be captured in order to gain information about their preferences. The latter method is popular in online book stores where products will be recommended on the basis of the purchasing behavior of customers who bought the product one is currently inspecting. Augmented group awareness tools employ social navigation principles (e.g. taking user ratings about non-observable entities) and combine them with group awareness principles. E.g., unlike in social navigation the information will be collected from group members one is actually interacting with, rather than from an anonymous collective. Moreover, the provided information does not refer to external products like books, but to products created by the particular group one is belonging to, viz. their discourse contributions. In this respect augmented group awareness tools are a hybrid between social navigation tools and classical group awareness tools.

A second extension of classical group awareness research that our work is exploring relates to the application of augmented group awareness tools to the field of CSCL. Very few attempts have been made in this direction, and the few applications in this field either focus on observable entities like learner activities (thus being classical group awareness tools) or provide information for the observing scientists rather than the group itself (cf. Jermann et al., 2001, for an overview). It is an open question whether groups make use of awareness-related information, how they use it, and if the use reflects in different kinds of group behavior. In any case augmented group awareness tool provide a somewhat novel technology metaphor. While some CSCL approaches use technology as an unstructured medium (potentially leading to learner disorientation), and while other approaches rely on rather directive means of structuring collaboration (potentially leading to overscripting; Dillenbourg, 2002), augmented group awareness tools provide a middle ground between these two extremes. They are designed to engender completely autonomous, but well-informed learner actions.

We have set out to explore the use and usefulness of augmented group awareness tools for collaborative learning scenarios. Our current work focuses on a general group awareness tool that is designed to support both synchronous and asynchronous forms of online group discussions. The basic idea here is to require learners to rate the written contributions in an online discussion on one or more dimensions. The tool itself performs the functions of a) taking the learner ratings as input; b) aggregating and/or transforming these inputs; and c) visualizing and feeding back transformed contextual variables as graphical output to the group. In this way learners are informed about the current state of the group with respect to some contextual variables in real-time.

Minority Influence in Collaborative Learning

In order to test the usefulness of these augmented group awareness tools we applied them to a particular scenario of collaborative learning, viz. the case of controversies and conflicting viewpoints. According to educational theorizing, controversies and conflicts are often seen as important antecedents of collaborative learning (Doise & Mugny, 1984). Some collaborative learning methods are even specifically tailored to engender a controversial discussion among learners, e.g. Structured Controversy (Johnson & Johnson, 1992). Despite the potential of controversies to facilitate elaboration of and negotiation among learners, there might be some pitfalls to these methods. The social psychological research literature points at various deficiencies of controversies because they can give rise to patterns of social influence that might be detrimental to a group's functioning, particularly if the sub-groups advocating the viewpoints are of different size. For instance, there is an abundance of social psychological literature that points at the difficulties that minorities in a group have on influencing conflicting majority viewpoints (Asch, 1956), especially if the task at hand is not demonstrable (i.e. a particular viewpoint cannot easily be proven to be a correct one). If this robust finding is applied to collaborative learning one can only assume that controversial discussions in a learning domain are also prone to the influence of a majority, irrespective of the validity or justifiability of the majority viewpoint. Generally, the suppression of minority viewpoints would be detrimental to collaborative learning because it prevents groups from gaining divergent, flexible perspectives on a particular domain. These detrimental effects of lacking minority influence are even exacerbated when the minority holds a scientifically correct viewpoint that fails to influence an incorrect majority perspective. Given that collaborative learning requires the joint construction of a shared understanding it could well be the case that in such a scenario the minority would rather comply with the incorrect majority perspective than vice versa.

In the context of group-decision making these patterns of social influence are often investigated in a quantifiable manner by employing so-called hidden profiles (Stasser & Titus, 1985) with an informed minority. In these scenarios a minority group member receives unshared, critical information that should lead to a different, but better group decision quality than the shared pieces of evidence that the majority members receive. In addition to the general finding that groups are often unable to uncover a hidden profile (i.e. identifying the best alternative) studies employing an informed minority have shown that groups focus less on critical (minority-held) information when the task did not appear to be demonstrable (Stewart & Stasser, 1998), that minority influence was even diminished when groups were using an anonymous group decision support system (McLeod, Baron, Marti & Yoon, 1997), and that the discovery rate of the best decision alternative (out of three) was only 10% using an informed minority (Brodbeck, Kerschreiter, Mojzisch, Frey & Schulz-Hardt, 2002).

However, social psychology has also outlined several conditions that should lead to enhanced minority influence. These beneficial principles are important because they informed the particular design of our augmented group awareness tool. For instance, it was reported that minorities exert more influence over majorities if they appear consistent in their argumentation even in the face of controversy (Moscovici, 1976). If members consistently perceive that there is a conflict in the group, efforts to resolve conflict and seek for a resolution are likely to be maintained rather than ignored. A second important antecedent for minority influence stems from the theoretical distinction between normative and informational influence (Deutsch & Gerard, 1955). The influence of a majority on the minority is normative, i.e. minorities often conform to the majority viewpoint because of social pressure. The influence that a minority can have on the majority, however, is usually informational influence, i.e. majorities will be more likely to conform with a minority viewpoint if the arguments brought forth by the minority are particularly persuasive. Similarly, Nemeth (1986) has reported that a key factor in minority influence is the potential novelty of the arguments brought forth.

The design of our augmented group awareness tool for the informed minority scenario was building on these principles via two mechanisms. First, group members were required to rate their agreement with a given contribution. Because one could expect that average agreement with minority contributions is lower than for majority contributions, the visualized arithmetic means of agreement ratings should visually separate majority and minority contributions. This would serve as a constant reminder to the group that a conflict might still exist between viewpoints, thereby precluding false consensus. Moreover, this visual separation of contributions should enhance the consistency of the minority viewpoint. Second, group members were required to rate the novelty of a given contribution. Here one could expect that the novelty of majority contribution is rated as relatively low (because majority arguments are shared, and tend to be redundant), whereas minority contributions should yield high novelty ratings. By emphasizing on the redundancy of contributions by a majority its normative influence might be decreased, whereas informational influence of the minority should be increased by focusing on their novelty. Thus, by making the unique contributions of a minority salient, it was expected that their influence on the (incorrect) majority viewpoint would be increased. A specifically designed group awareness tool requiring ratings of agreement and novelty should therefore lead to strengthened minority influence. This should be reflected in better group discussions, and due to using an informed minority paradigm lead to better group decisions and learning. This hypothesis was explored in an experimental study.

Method

In the study, small groups of four learners used a text-based online discussion environment in order to come to an agreement on a conflicting physics topic. Similar to the *informed minority* paradigm (Stewart & Stasser, 1998), learning material, consisting of pieces of evidence, was previously distributed across the group members in such a way that one learner – the informed minority – received information that should lead to a scientifically correct viewpoint on the issue, whereas three other learners (majority members) received information that should lead to a plausible, but incorrect viewpoint.

Design

Two experimental conditions were compared that differed with respect to the support learners received regarding the awareness of other group members' contributions during the online discussion. While learners in the control condition were only provided with an online discussion environment, learners in the treatment condition were additionally provided with a rating-based augmented group awareness tool.

Participants

64 students (26 males and 38 females, ages 19 to 31; $M = 22.05$; $SD = 2.35$) at the University of Tübingen were randomly assigned to the two experimental conditions and – within the small groups – to the minority or to the majority. They were paid for their participation. To prevent a very high level of prior knowledge physics students were excluded from participation.

Materials

The application domain was comprised of physics concepts concerning light propagation.

The instructional material was taken from the web-based inquiry science environment WISE module "How far does light go" (Bell, 1995). The entire pool of learning material consisted of six pieces of evidence concerning light propagation. Two pieces of evidence were in line with a scientifically plausible, but incorrect viewpoint ("Light dies out"), whereas three pieces of evidence were supporting the scientifically correct viewpoint ("Light goes forever"). A sixth piece of evidence was irrelevant with respect to the conflicting viewpoints. The six pieces of evidence were distributed across the group members prior to the group discussion according to the informed minority paradigm of Stewart and Stasser (1998). The three majority members received four pieces of evidence each: two (shared) information pieces supporting the incorrect viewpoint; one (unshared) information piece about the correct viewpoint; and the irrelevant piece of evidence. Taken together, the information distribution in the majority was identical to a hidden profile, i.e. each member would be more likely to prefer the incorrect alternative based on shared information, whereas a group's preference should shift towards the correct alternative if the unshared information pieces were pooled during discussion. The fourth member of the group (informed minority) received all six pieces of evidence which should lead to a preference for the correct viewpoint. Prior tests revealed that this type of information distribution predicted learner preferences quite accurately, i.e. independent learners who received the same material as the minority, tended to favour the correct viewpoint, whereas learners who received the same material as the majority, were biased in favour of the incorrect viewpoint.

The online discussion environment used in both experimental conditions was developed at the Knowledge Media Research Center in Tübingen as part of the groupware system VisualGroup (in its current version renamed as Bebop). It enabled the small groups to discuss in a text-based and synchronous way. Contributions were listed sequentially in temporal order. To control for effects of acquaintance among participants actual names were replaced by neutral handles ("person A" etc.), i.e. contributions were made anonymously. *The group awareness tool* provided to the small groups in the treatment condition was embedded into the online discussion environment. It consisted of (1) seven-point Likert rating scales that allowed learners to rate each contribution (except their own) with respect to (a) the agreement with a contribution, and to (b) the novelty of a contribution in the discussion, and (2) a visualization of the contributions represented as dots on a two-dimensional graph, where the x-axis represented the average agreement rating, and the y-axis represented the average novelty rating that a given contribution received. The visualization was personalized in that learners could distinguish their own contributions from other group members' contributions, and by indicating contributions a learner hadn't rated yet (Figure 1). By clicking on a particular dot in the visualization learners could read the corresponding contribution.

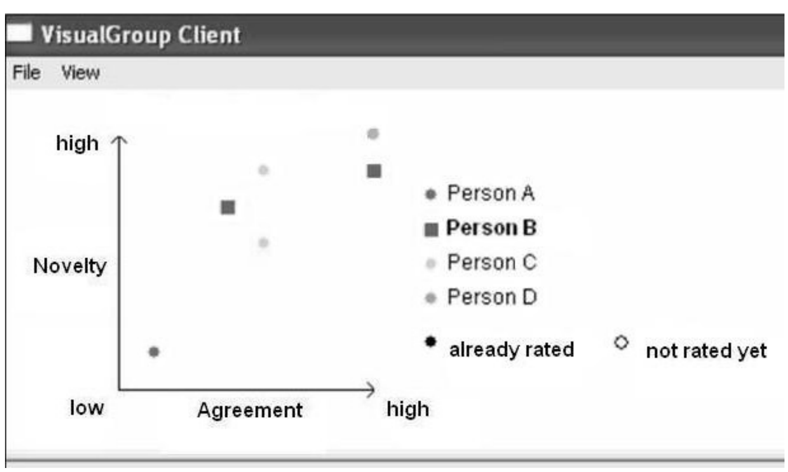

Figure 1. Screenshot of the visualization used (translated from German).

The test material for assessing the knowledge of the learners consisted of two test sheets that were individually administered before and after group discussion. The first test sheet required participants to state their preference for one of the two controversial viewpoints, and to indicate their confidence with this rating. The second test sheet which was administered after the discussion asked learner to state the decision that the group arrived at. Moreover, learners were required to indicate their individual preference for one of the controversial viewpoints, and a confidence rating for the individual decision.

Measures

Group decisions (correct vs. incorrect decision) were extracted from the contents of the group discussions. Since subjects were also individually required to explicitly state the group decision after the discussion, these data could be used in cases where the actual group decision was not evident. It was expected that groups in the treatment condition would make better group decisions than groups in the control condition.

Measures of learning were derived from the decisions among the two conflicting viewpoints that both the groups and the individuals made after discussion. In order to gain access to a rough indicator of individual learning the preferred decision alternative and the confidence ratings were used to calculate a correctness value of the decision ranging from 0% (wrong answer and confidence rate of 100%) to 100% (correct answer and confidence rate of 100%). It was expected that in treatment groups (with augmented awareness tool) minorities would exert a greater influence on the group decision, thereby yielding higher correctness values across group members.

Discussion parameters were derived as indicators for knowledge building processes. Log files of the discussion contents were used to generate general measures of participation (e.g. number of written contributions). The discussion content was additionally coded by two independent coders. Single contributions were rated according to three categories (knowledge construction; negotiation of preferences; others). It was expected that groups in the treatment condition would display a lower number and rate of contributions rated as negotiation of preferences because the visualization already contained the corresponding information. As a consequence, it was tentatively hypothesized that this might lead to a higher number and rate of knowledge construction contributions. On the level of the whole group discussion sessions independent coders additionally categorized the deliberation style of groups. Deliberation style is a concept drawn from research on mock juries. E.g., Hastie, Penrod and Pennington (1983) have found that some juries discuss evidence-driven, i.e. they start by exploring the evidence before integrating the evidence into a verdict. Other groups, however, are verdict-driven, i.e. they start by collecting and integrating individual verdict, and then start a (biased) search for information in support of this verdict. It was expected that without augmented group awareness tools groups might be tempted to reach a consensus overly quickly, thereby employing a verdict-driven style. Due to the small sample size deliberation style of groups was only analyzed in descriptive terms.

Procedure

The experiment consisted of two phases: an individual learning phase, and a group discussion phase. During the entire experiment subjects of a group were seated in separate rooms. In the first phase learners received information about light propagation individually (10 minutes). While the information distribution was identical across conditions, it differed within the small groups according to the informed minority paradigm of Stewart and Stasser (1998), as described above. Subsequent to the individual learning phase, but prior to the group discussion, individual preference and confidence were measured. After the learning phase individual group members were given the opportunity to test the online discussion environment by writing contributions. Group members in the treatment condition were additionally asked to rate test contributions by other participants.

In the second phase groups were instructed to discuss the conflicting viewpoints. All learners were made aware that other group members might have received different pieces of evidence. Groups were asked to make a decision about the conflicting viewpoints within the allotted discussion time (30 minutes). According to the experimental design of the study small groups in the control condition were only provided with the online discussion environment, while small groups in the treatment condition were additionally provided with the group awareness tool. After the discussion phase individual learners were asked to repeat the group decision, state their individual preference and indicate the confidence in their individual preference. Subjects were briefed about the study at the end of the experiment.

Results
Manipulation check
Across both conditions, all minority subjects showed a preference for the correct viewpoint, as indicated by pre-discussion choice. However, among the majority members only 41 out of 48 subjects chose the incorrect viewpoint. The distribution of pre-discussion choices between the two conditions was not different, i.e. out of the 7 subjects that did not adhere to the manipulation, 3 were in the condition without group awareness tool vs. 4 in the experimental condition, thus yielding no significant differences between conditions – ($\chi^2(1, N = 64) = .68$, n.s.). Although results using actual pre-discussion choice as independent variable were slightly more favorable with respect to the hypotheses, results described in this paper are based on the more conservative independent variable of member status (majority vs. minority), as intended by the manipulation.

Group decisions
Among the eight groups using the augmented group awareness tool, six arrived at the correct group decision vs. two for the incorrect decision. In contrast, groups without group awareness support arrived at the incorrect decision in six cases, at the correct decision in one case, while one group did not arrive at a conclusion during the allotted time. The difference in arriving at the correct solution is significant between conditions (χ^2 (2, N = 16) = 6.57, $p < .05$). This provides evidence that augmented group awareness tools were reversing the bias towards majority opinion.

Individual correctness
Table 1 shows the correctness values for minority and majority subjects within the treatment and control condition. A 2x2 analysis of variance (ANOVA) with support and member status as independent variables yielded a significant main effect for member status; $F(1,60) = 4.74$, $p < .05$. The main effect for support and the support x status-interaction approached significance ($p = .08$ in both cases). However, the data from Table 1 show that majority members in the treatment condition were scoring much higher than majority members in control groups. An additional, one-tailed t-test revealed that this difference was highly significant; $t(46) = 3.56$; $p < .01$. In other words, there is evidence for the hypothesis that majority members moved from the incorrect to the correct viewpoint if they were using an augmented group awareness tool.

Table 1: Individual correctness values for learners across member status (majority vs. minority) and support (treatment vs. control).

Support		**Status** Majority	Minority	Overall
Control	M	37.17	78.63	47.53
	SD	36.89	32.51	39.76
Treatment	M	74.58	78.38	75.53
	SD	36.02	36.18	35.51
Overall	M	55.88	78.50	61.53
	SD	40.72	33.23	39.97

Discussion parameters
Table 2 shows the absolute number of contributions written by majority and minority members across the two conditions, separated by the three coding categories (knowledge construction, negotiation of preferences, other). Results of 2x2-analyses of variance (ANOVA) indicate that members from control groups wrote more contributions than group members in the treatment condition; $F(1,60) = 21.75$, $p < .01$. No differences were found for member status or the support x status-interaction. A main effect for support could also be found by only taking into account messages that were coded as knowledge construction contributions; $F(1,60) = 5.70$, $p < .05$. However, an analysis of relative amounts of knowledge construction messages reversed this effect; $F(1,60) = 6.49$, $p < .05$. In other words, treatment groups produced a higher relative amount of knowledge construction contributions than control groups ($M = .67$, $SD =.18$ vs. $M = .51$, $SD = .17$).

Table 2: Number of contributions across conditions that were coded as knowledge construction (KC), negotiation of preferences (NP), or others.

Support		Majority			Minority			Overall		
		KC	NP	Other	KC	NP	Other	KC	NP	Other
Control	M	9.37	4.67	3.63	10.63	5.13	2.63	9.69	4.78	3.38
	SD	6.11	2.76	2.00	7.33	4.49	1.92	6.33	3.20	2.00
Treatment	M	6.21	2.21	.50	7.00	3.00	1.38	6.41	2.41	.72
	SD	2.86	1.38	.66	2.27	1.93	.92	2.71	1.54	.81
Overall	M	7.79	3.44	2.06	8.81	4.06	2.00	8.05	3.59	2.05
	SD	4.98	2.49	2.16	5.56	3.51	1.59	5.11	2.76	2.02

The descriptive analysis of the groups' deliberation style indicated that seven out of eight control groups were following a verdict-driven style. Four of the treatment groups were using an evidence-driven style of deliberation vs. three verdict-driven groups. The remaining two groups in both conditions were not uniformly classified among raters. In others words, a deliberation style that started with collecting evidence before arriving at a decision was only to be found in treatment groups. Additional analyses revealed that all four evidence-driven groups, the two mixed-style groups and only one of the verdict-driven groups arrived at the correct group decision. In contrast, all verdict-driven groups made a decision in favor of the incorrect majority viewpoint.

Discussion

An experimental study showed that group using an augmented group awareness tool showed a higher performance in terms of group decision and individual correctness than unsupported discussion groups.

On a larger scale addressing the entire CSCL community one of the most interesting findings of the study was the fact that majority influence indeed occurred in the unsupported control groups. It was often mentioned that CSCL tends to look at positive results, thereby neglecting instances where collaborative learning might actually fail. Our studies have shown that in learning scenarios social psychological factors like majority influence are at work. While this might not be surprising to social psychologists, this point is hardly addressed in the CSCL literature. We hope that in the future findings from social psychology will be merged with findings from CSCL, thereby arriving at a clearer picture of collaborative learning.

While it appears that collaborative learning groups might arrive at suboptimal solutions because of an overpowering majority influence, our experiment indicated that this inherent bias can be overcome by technological means. An augmented group awareness tool specifically designed to focus on learner ratings of agreement and perceived novelty significantly increased minority influence, thereby leading to better group and individual learning performances. Of course, in natural learning settings it is not always the case that a correct minority is facing an incorrect majority. However, it can be expected that minority viewpoints frequently occur, and they tend to be overlooked, irrespective of their correctness. Therefore, augmented group awareness tools should contribute to a more thorough consideration of diverse viewpoints, a goal that probably aligns with a huge range of CSCL accounts. The benefit of allowing for diversity was also illustrated in our analyses of deliberation style. Whereas control groups were frequently focusing on finding an initial verdict, followed by identifying supporting evidence, it appears that the augmented group awareness tool used in the treatment groups led to a much more open, evidence-driven discussion before groups settled on a decision.

Although outcome measures indicate differences between conditions the more general question of what mechanisms might have produced the obtained results were not explicitly addressed thus far. In other words, what parts of the augmented group awareness tools were conducive to strengthened minority influence? On the one hand, simply requiring learners to rate contributions might lead them to reflect on the content, to serve as a metacognitive prompt, and thereby leading to minority influence and better learning outcomes. This potential effect would hold even in the absence of a visualization. On the other hand, the visualization might exert specific influence on learner behavior by making aspects of collaboration particularly salient (e.g. novelty of a contribution), thereby guiding learners' attention to relevant information. Of course, both mechanisms might as well work additively. We will test these two conflicting explanations in a follow-up study that includes a ratings-only condition. Another interesting question is what actually happens when a majority member shifts preference. Is it because convincing arguments were brought forward (content-related) irrespective of their source, or is it because these arguments were brought forward by a particular source (person-related). In our present experiment the identity of authorship was confounded with the content, i.e. contributions in the visualization were color-coded with respect to the authors. The follow-up study will disentangle these effects by either using a non-color-coded visualization of contributions (content-only), a visualization that only displays the group members as dots (person-only), or a combined visualization.

Future Directions

It is apparent that the augmented group awareness tool used in this study was specifically tailored to scenarios of majority-minority conflicts. However, it can be assumed that the general type of rating-based augmented group awareness tools can be adapted to other scenarios as well. For instance, other studies could investigate this tool not for group awareness, but for social navigation in a stricter sense by requiring learners not to mutually rate their contributions, but to rate external sources like learning materials. For other scenarios it might be suitable to visualize the given instead of the received ratings. Moreover, depending on the research question learners could rate contributions on different dimensions, e.g. liking, conclusiveness. The tool itself could use different means of aggregation and visualization. Whereas the tool in the current study was simply using arithmetic means of agreement and novelty, other tools could visualize standard deviations (an indicator of the degree of conflict), correlations, or even make use of advanced statistical procedures like cluster analysis and factor analysis in real time. Finally, it will be an interesting question to compare direct social navigation (explicit ratings) with indirect social navigation where learner behavior will be implicitly captured. In the social navigation literature indirect social navigation algorithms are often regarded as superior because they do not burden subjects with the potentially tiresome task of rating contributions. However, our discussion on the explanatory mechanisms for minority influence in this experiment might indicate that this additional burden might be a key factor in producing favorable learning results.

Conclusions

We believe that augmented group awareness tools enrich our repertoire of CSCL technologies both for practical use and for scientific inquiry. Whereas some considerations for the scientific investigation of these tools were addressed in the preceding section, it is evident that practical use of augmented group awareness tools faces additional hurdles. Issues of learner compliance and scalability across group sizes are the first that come to mind. Research into practical use of these group awareness tools might be conducted in mobile learning scenarios, thereby taking into account affordances and constraints of this particular technology.

In terms of the scientific analysis of tools we believe that they are open to investigations based on a range of epistemologies (Suthers, 2006). While many processes involved in collaborative learning can be made visible and quantifiable with these tools, thereby lending themselves to an experimentally-oriented epistemology of knowledge communication, it is of course possible to hermeneutically describe and analyze knowledge building processes that take place during group discussions, and examine the ways they unfold under the influence of ratings and/or visualizations. On a final note, it should be repeated that augmented group awareness tools as described in this study stand for a potentially new philosophy of learner guidance. While they are far from being as directive as other methods (e.g. scripted cooperation), they avoid the pitfall of leaving collaborative groups without any guidance. Being well-informed, but fully autonomous might be an interesting metaphor for collaborative learning that is well worth studying in entirely different contexts of CSCL.

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Boda Blocks: A Collaborative Tool for Exploring Tangible Three-Dimensional Cellular Automata

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Abstract: Construction kits like traditional building blocks provide excellent media for face-to-face collaborative interaction. The complexity and expressive power of these kits are increasingly being augmented with computational elements like controllable lights, motors and sounds. This paper introduces a computationally enhanced set of building blocks, *Boda Blocks*, which allows for collaborative interaction through the construction and programming of tangible three-dimensional cellular automata. We provide a brief introduction to computationally enhanced construction kits, describe the Boda Blocks system and report on the results of a preliminary user study.

Introduction

Construction kits constitute a venerable tradition in the design of educational toys. Kits allow for a relatively unselfconscious medium in which children can work both alone or in collaboration; unlike (on the one hand) explicitly solitary activities such as reading, or (on the other) explicitly group-oriented activities such as board games, construction kits allow for both individual contemplation and group discussion.

Researchers and designers have recently begun to integrate computation and construction kits in various ways. This trend began in the 1970s when architectural researchers (Frazer 1994; Aish 1979) built beautiful kits for architectural modeling. Such kits have entered the educational realm more recently (Eisenberg et al. 2002; Resnick et al. 1996). The Active Cube (Watanabe et al. 2004) and Topobo (Raffle 2004) projects, as well as the work of Wyeth et al. (2002) and Zuckerman et al. (2005) are especially inspiring examples of educational kits.

Boda Blocks

This paper describes a computationally-enhanced construction kit, *Boda Blocks*. The kit, shown in Figure 1, is a set of 16 luminescent cubes that can be arranged in a variety of configurations and programmed, via companion software, with cellular automaton rules to display dynamic three-dimensional patterns of light and color.

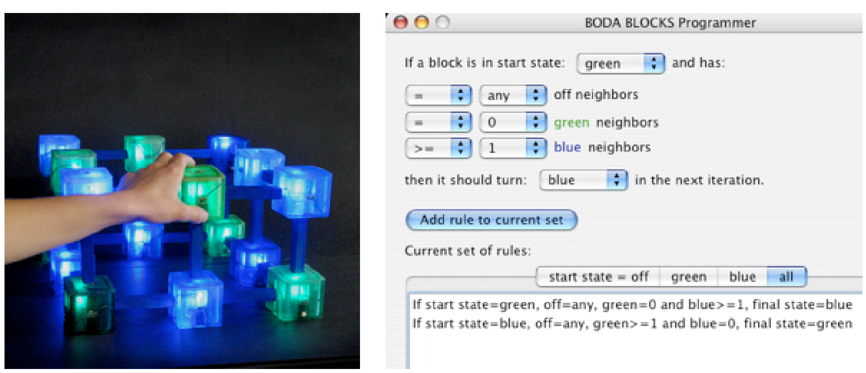

Figure 1. Boda Blocks: the physical kit and the programming interface.

Each block is always in one of three states: blue, green, or off. Boda Block constructions are in one of two modes at any given time. In the *interacting mode*, users can program the blocks with cellular automaton rules and use the switches on individual blocks to set a construction's initial state. (Pressing a switch on a block cycles its state from blue to green to off.) In the *executing mode*, constructions evolve according to the cellular automaton rules with which they have been programmed. Users can change the physical configuration of a construction at any time by adding blocks to it or removing blocks from it. Thus, there are four actions that are undertaken with the kit during its two modes: constructing, programming, initializing and observing.

Cellular automata are mathematical models that explore how local rules, executed in discrete time steps, can result in complex global patterns (Ilachinski 2001). Cellular automata are usually implemented on a computer screen on a grid of colored “cells” (the squares in the grid). Cells can display their “state” through their color, and can communicate with their immediate neighbors (usually the squares surrounding them). As a cellular automaton develops in discrete time steps, each cell computes what its state will be at time t+1 based on its state and the state of its neighbors at time t; the patterns that evolve in a particular cellular automaton are dependent on the initial state of the grid.

Cellular automaton rules for the Boda Blocks are defined using the cellular automaton programming software, shown in Figure 1. This software allows users to experiment with a specific class of cellular automaton rules. This class of rules, termed outer-totalistic (Ilachinkski 2001, p. 45), allows users to specify a block’s next state based on its current state and the collective behavior of its neighbors.

Any blocks that are part of a construction will be reprogrammed with the new rule set when it is sent; blocks that are not part of the current construction will not be reprogrammed. We would like to call attention to the fact that this design allows for the interesting possibility of constructions with heterogeneous rules; that is, a single construction may contain blocks that have been programmed with an assortment of rules. During the executing phase, a construction functions as a parallel computer. Each block simultaneously and independently communicates state information to and receives state information from its neighbors (any blocks that are attached to it) and then independently updates its state based on its personal rule.

Preliminary User Testing

We recently held the first user test of the Boda Blocks system. The test took place in our lab with a group of four children ages 11-14, two females and two males. The questions we were most interested in answering at this preliminary stage were: “Is the kit usable?” and “Is the kit engaging; is it capable of maintaining sustained user interest?” Our principal means of assessment for these questions was observation. We took several photographs, and noted down interesting quotes, but otherwise did not impose on our users. The remainder of this section will report on this initial study, highlighting issues surrounding collaboration.

The four children spent approximately one hour interacting with the Boda Blocks system. A pile of blocks and connectors was placed on a table, and users could sit around three sides of it to interact with the system. A laptop was provided for the block programming activity. To begin the Boda Blocks session, a workshop leader (the first author) explained the Boda Blocks phases and activities: constructing, programming, initializing and executing. The participants then quickly began building constructions with their pile of blocks and connectors. They experimented with a few different configurations, but after building the tower form seen in Figure 2, did not return to the construction activity. The rest of the session was spent experimenting with different rules and initial configurations set on this form.

Figure 2. Users interacting with Boda Blocks.

Once the tower was built and connected to the computer, each child was given the opportunity to program the construction in turn. While one child manipulated the programming interface, the other children either worked on setting the initial state of the blocks, observed executing behavior, or assisted the programmer with her task.

Figure 2 shows images of typical interaction: in the left image, two children interact with the kit simultaneously while one observes; in the right image, two children collaborate on the programming activity while a third works on setting the blocks' initial configuration.

The interaction was immediately highly collaborative and remained so throughout the session. Participants kept up an ongoing and lively discussion about the rules, initial states and dynamic patterns. Interaction between the programmers and block manipulators was coordinated and productive. Initially, the participants seemed to somewhat randomly experiment with rules and behavior, but as they observed interesting patterns—one that died out for example—they attempted to modify the rules and starting state to obtain intentional results—a pattern that did not die out, or one that oscillated.

The users also became immediately engaged in predicting the behavior of their constructions. Given an initial state and a rule, they would almost always embark on a period of collective speculation and initial state modification before executing their construction. Often the observed behavior would confound their expectations, usually because they had neglected to fully think about all three dimensions. For example, expecting an oscillating pattern on a horizontal plane, users were surprised when their construction evolved into a seemingly random flashing pattern. After first protesting that "the blocks are broken!" the users then reset the initial configuration and realized that they had neglected to take vertical interactions into account. This pattern of experience was repeated many times throughout the session, with users periodically experiencing three-dimensional "aha" moments.

At the end of the session we felt that we had achieved a good informal indication that our kit was indeed useable and engaging. Since our assessment was based entirely on observation we cannot be certain that each of the participants completely understood the system and felt comfortable with it, but our initial findings were positive. As has been detailed, the users built their own constructions successfully and were quite capable of interacting with the system with very little intervention. All of the users seemed to quickly understand the relationship between programs, the blocks' starting states and the patterns that they observed in the blocks.

We also found that the kit sustained the users' interest throughout the one hour session. Somewhat to our surprise, the children remained independently engaged and actively explored different rules and behaviors without outside prompting. As was stated above, we did periodically intervene to make sure that each child had a turn at the computer to program the blocks, but other than that we did not structure the experience. Participants seemed to genuinely enjoy working with the kit. Indeed, the participants were reluctant to leave the workshop at the end of the session, as they were immersed in attempting to get their construction to exhibit a desired behavior.

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The Organization of Collaborative Math Problem Solving Activities across Dual Interaction Spaces

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Abstract. In this paper we focus on the organization of activities that produce shared graphical representations on the whiteboard of a CSCL system with dual interaction spaces called VMT Chat, and the ways these representations are used in conjunction with chat postings as semiotic resources by interactants as they jointly make sense of and build upon each other's mathematical statements.

Keywords: Dual interaction spaces, interaction analysis, shared representations

Introduction

Dual Interaction Spaces (DIS), which typically bring together two synchronous communication technologies such as a text-chat and a shared workspace, have been widely used to support collaborative learning activities online (Dillenbourg & Traum, 2006; Mühlpfordt & Wessner, 2005; Jermann, 2002; Soller & Lesgold, 2003). The way such systems are designed as a combination of two technologically independent communication mediums bring significant interactional consequences for the users (Stahl et al., 2006; Mühlpfordt & Stahl, 2007). Despite the popular use of DIS in CSCL applications, there are only a few studies about how small groups organize their interaction in these environments. Existing approaches include: (a) modeling actions performed across both mediums and the problem space to seek relational patterns among ontological entities (Avouris et al., 2003); (b) employing content analytic methods to study the correlation between planning moves and the success of manipulations performed in the shared workspace (Jermann & Dillenbourg, 2005) and (c) the relationship between grounding and problem solving in DIS environments (Dillenbourg & Traum, 2006). In particular, by framing their analysis along the lines of Clark and Brennan's (1991) theory of grounding, Dillenbourg & Traum (2006) identify two kinds of uses of the dual spaces to facilitate grounding at various temporal levels during problem solving sessions, namely the napkin and mockup models. Moreover, since participants organized key factual information relevant to the problem at hand on the shared whiteboard during their experiments, the authors attributed a *shared external memory* status to this space and claimed that it facilitated grounding by offering a more persistent medium for *storing* agreed upon facts.

The notion of common ground as an abstract placeholder for registered cumulative facts or pre-established meanings has been critiqued in the CSCL literature for treating meaning as a fixed/denotative entity transcendental to the meaning-making activities of inquirers (Koschmann, 2002, p20; Stahl, 2006a, p354). As an alternative to previously proposed approaches that involve modeling of actions and correct solution paths, or treating shared understanding as alignment of pre-existing individual opinions, in Stahl et al (2006) we have begun to develop an interactional perspective to study the intersubjective meaning making activities of small groups mediated by DIS environments. In this paper we build on our previous work on referencing math objects in chat by focusing on the sequence of actions in which participants co-construct and make use of *semiotic resources* (Goodwin, 2000) distributed across dual interaction spaces to sustain their collaborative problem solving work on open ended math tasks (Stahl, 2006b). We also compare the affordances of both mediums based on the ways their contents were used as semiotic resources by the interactants.

Analysis

The data excerpts we used in this paper are selected from the time-stamped logs of collaborative problem-solving sessions sponsored by the Virtual Math Teams (VMT) project. VMT is an NSF funded research program through which researchers at the Math Forum and Drexel University investigate innovative uses of online collaborative environments to support effective K-12 mathematics learning. During these sessions participants interacted through a tool called VMT Chat, which provides a shared drawing area, a text-chat window, and a tool for explicit referencing that allow users to visually connect their chat postings to prior postings and/or to objects on the board (Mühlpfordt & Wessner, 2005). In the following subsections we present a summary of our overall findings[1] about the ways both spaces were used as semiotic resources by small groups of students as they collaboratively co-constructed and made sense of mathematical arguments in the VMT Chat environment.

Availability of the Production Process

Whiteboard and chat contributions differ in terms of the availability of their production process. In the chat area, participants can only see who is currently typing, but not what is being typed until the author decides to send his/her message. A similar situation applies to atomic white board actions such as drawing a line or a rectangle. However, the construction of most shared diagrams includes multiple atomic steps, and hence the sequence of actions that produce these diagrams is available for other members' inspection. Hence, the whiteboard affords an animated evolution of the shared space, which makes the visual reasoning process manifested in drawing actions explicit due to its instructionally informative nature.

Mutability of Chat & Whiteboard Contents

The two interaction spaces also differ in term of the mutability of their contents. Once a chat posting is contributed, it cannot be changed or edited. Moreover the sequential position of a posting cannot be altered later on. If the content or the sequential placement of a chat posting turns out to be interactionally problematic, then a new posting needs to be composed to repair that (Garcia & Jacobs, 1998). On the other hand, the object-oriented design of the whiteboard allows users to re-organize its content by adding new objects and by moving, annotating, erasing, reproducing existing ones.

Chat vs. Whiteboard Contributions as Referential Resources

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

Past and Future Relevancies Implied by Shared Drawings

As part of an ethnomethodological study of cognitive scientists' whiteboard use during design meetings in a face-to-face setting, Suchman observed, "…while the whiteboard comprises an unfolding setting for the work at hand, the items on the board also index an horizon of past and future activities" (1990, p317). VMT Chat's whiteboard serves a very similar interactional role, in the sense that what gets done now informs the relevant actions to be performed and messages to be posted subsequently, and what was done previously can be reproduced or reused depending on the circumstances of the ongoing activity. Moreover, the drawings on the board have a figurative role in addition to their concrete appearance as illustrations of specific cases. The particular cases captured by concrete, tangible marks on the board are often used as a resource to investigate and talk about general properties of the mathematical objects indexed by them.

Discussion

In this study we attempted to highlight how small groups use shared representations and chat messages together as semiotic resources in mutually elaborating ways during their collaborative math problem solving activities in the VMT Chat environment. The complex relationships between the actions that took place across both interaction spaces made it difficult for us to describe what we have observed by using either the mockup or napkin models offered by Dillenbourg & Traum (2006). Instead, we have observed that in the context of an open-ended math task groups exhibit each type of organization during

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[1] Due to space limitations we could not include excerpts that illustrate the findings reported in this manuscript

brief episodes in the course of their entire session depending on the contingencies of their ongoing problem solving work. For instance, during long episodes of drawing actions where a model of some aspect of the shared task is being co-constructed on the whiteboard, the chat area often serves as an auxiliary medium to coordinate the drawing actions (i.e. mockup model); whereas when a strategy to address the shared task is being discussed in chat, the whiteboard is mainly used to quickly illustrate the ideas stated in text (i.e. napkin model). Moreover, we have observed that the whiteboard not only serves as a kind of shared external memory space to keep a note of the agreed upon facts, but also provides semiotic resources that participants rely upon as they make sense of the unfolding sequence of actions. The availability of the contributions posted on both spaces constitute an evolving historical context in which participants decide upon relevant steps to pursue next and make sense of new contributions in relation to the semiotic resources persistently available on the shared visual field.

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Fostering Knowledge Building Using Concurrent, Embedded and Transformative Assessment for High- and Low-Achieving Students

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Abstract: We describe the design of a knowledge-building environment and examine the roles of knowledge building principles and portfolios as scaffolds in fostering collaboration for students of different achievement levels. Students assessed their contribution in Knowledge Forum™ using rubrics and they wrote electronic portfolios and group reviews to assess both individual and community progress. We used a 2 x 2 design (knowledge-building principles x achievement) with four classes of 9th grade students (n = 141) working on Knowledge Forum. We obtained the following results: (1) Students scaffolded with knowledge-building principles showed more participation and conceptual understanding than students working on Knowledge Forum with no principles; the effects were more pronounced for low-achievers compared to high-achievers, (2) Students' portfolio scores predicted domain understanding over and above the effects of academic achievement, and (3) Analyses of knowledge-building discourse and portfolios showed how students made progress in their collective knowledge advances.

Keywords: knowledge building, collaborative inquiry, assessment, electronic portfolio.

Introduction

There is now much interest in examining collaborative inquiry and specifically how computer-mediated discourse can promote learning and understanding (Koschmann, Hall, & Miyake, 2002). With major shifts from individual towards social views of learning (Paavola, Lipponen & Hakkarainen, 2004; Sfard, 1998), Bereiter and Scardamalia proposed that schools and classrooms should be re-structured to foster a social process of progressive knowledge building guided by the 'Knowledge-Building Community' Model (Bereiter, 2002; Scardamalia & Bereiter, 2006). The theoretical ideas of this model, namely, 'intentional learning' (Bereiter & Scardamalia, 1996), 'the process of expertise' (Bereiter & Scardamalia, 1993) and 'schools as knowledge-building communities' (Bereiter & Scardamalia, 1996) are mediated in a computer learning environment called Knowledge Forum™ (Scardamalia & Bereiter, 1994). Students pose questions, theories and explanations, and use graphics in the computer database as they engage in collaborative problem-centred inquiry. The epistemology of Knowledge Building, supported by the software, Knowledge Forum, aims at helping students view knowledge as an object of inquiry, and improving the knowledge of the community. Scardamalia (2002) has postulated a set of knowledge building principles for characterizing the dynamics of knowledge building emphasizing the need for students to pursue and improve ideas for collective advances as in a research community.

Decades of research have shown the roles of knowledge building in advancing student understanding (e.g., Hakkarainen, 2003; Scardamalia, Bereiter & Lamon, 1994; Zhang et al., in press). Although there has been much progress, there continue to be major challenges to the recognition and assessment of collective knowledge building, a major theoretical issue in research on computer-supported collaborative learning (CSCL) and a key pedagogical issue for teachers implementing knowledge building. In addition, there is a general belief that knowledge building and related sorts of high-level learning goals of metacognition and epistemic agency are only attainable by high achievers rather than the mediocre and low-achieving learners. Such beliefs persist despite research indicating the role of higher-order thinking for low-achieving students (e.g., Zohar & Dori, 2003) and they form barriers to teachers engaging in knowledge building in their classrooms. We need to examine how knowledge building can be assessed in classrooms and how assessments can be used to guide improvements in knowledge building. We are particularly interested in examining the notion of concurrent, embedded and transformative assessment (Scardamalia, 2002), emphasizing students' *epistemic agency* in assessing their own and community progress. We believe that student assessing their own knowledge building can take epistemic agency to a high form, thus serving the dual roles of assessing and fostering collaboration. We also sought to examine if collective knowledge building focusing on community progress might be relevant for students of diverse backgrounds.

We continue with our ongoing research program proposing that "assessment" in CSCL should serve the dual roles of characterizing and fostering knowledge building, and that students can play major roles in assessing their *collective* understanding (Lee, Chan & van Aalst, 2006; van Aalst & Chan, 2007). Due to epistemological changes and new understandings about learning, the form, content and use of assessment should aim at understanding stemming from the student's point of view (Shepard, 2000). Since knowledge construction is an ongoing process, evidence of learning, should, therefore, be provided by learners themselves based on knowledge-advancement criteria. In our earlier studies we have examined the characterization and fostering of knowledge building through the use of e-portfolio in Knowledge Forum -- Students were asked to identify clusters of notes that best illustrate knowledge building episodes guided by some principles; we found these knowledge-building portfolios could both characterize and foster knowledge building (Lee et al., 2006; van Aalst & Chan, 2007).

The present paper continues this line of inquiry addressing the problem of assessing individual and collective knowledge advances in fostering collaboration for students of different abilities. There are several refinements in our design. First we aimed to extend our work to see how knowledge building and reflective assessment could work for students of different achievement levels, thus addressing problems of barriers to implementing knowledge building in classrooms. We included students with different achievement groupings to examine more clearly how knowledge-building pedagogy might influence students of different backgrounds. Second, we used reflective assessment more intensively -- In the previous studies students were asked to produce electronic portfolios documenting high points in knowledge building. In this study, from the start, students were engaged in using depth of inquiry and explanation *rubrics;* they were asked to produce both portfolios and group review journals to capture the best knowledge-building incidents, thus exploring both *individual* and *community* progress more deeply. Third, we tracked more closely student growth and knowledge advances in the community through analyzing a major inquiry thread in student discourse.

This paper describes our continuing work in exploring and refining the design of student-directed assessment in characterizing and fostering collaboration. We investigated specifically several Knowledge Forum classrooms examining students assessing their own discourse with or without knowledge-building principles. Building on earlier work, we expected that using peer assessment and making assessment criteria explicit would help students engage in more knowledge building and domain understanding. We also examined whether knowledge-building portfolio assessments could also work for students of different abilities. There were several objectives: (1) To examine if students using knowledge-building principles in writing notes and portfolios showed more participation and conceptual understanding compared to their counterparts, and to examine such effects on students with different achievement levels, (2) To examine the roles of knowledge-building and portfolios on domain understanding, and (3) To investigate growth in the community and to examine how knowledge building principles can characterize and scaffold collective knowledge advances.

Method

Participants

The participants were 141 students studying in four grade-nine Geography classes in a regular high school in Hong Kong. The students at this school studied from English textbooks and wrote in English in Knowledge Forum. The students were taught by an experienced geography teacher with over 15 years of teaching experience; he also had several years of experience using Knowledge Forum. The teacher taught all 4 classes. Students in Grade 9 were streamed into different classes by academic achievement based on school examination results. This study used a 2 x 2 design (knowledge-building principles x achievement); the four classes all used Knowledge Forum and they included (a) High-Achieving with Knowledge-Building Principles, (b) High-Achieving with no Knowledge-Building Principles, (c) Low-Achieving with Knowledge-Building Principles and (d) Low-Achieving with no Knowledge-Building Principles.

Design of the Learning Environment

Knowledge Forum was implemented in the geography curriculum in the second semester of the year (Feb-May). The teacher integrated knowledge-building pedagogy with the school curriculum; several curriculum units were taught including "Oceans in Trouble: Scarcity and Economic Development", "Rich and Poor: Poverty and Economic Development", "Saving Our Rainforest: Sustainability and Economic Development". Teachers conducted class discussion during school and students were asked to deepen their understanding of the course materials through the use of KF after school. We briefly describe the design of the knowledge-building environment:

1. Cultivating a Collaborative Culture. Before the implementation of Knowledge Forum, all students were provided with learning experiences to familiarize them with collaborative learning. Such learning experiences are particularly important for Asian students who are more used to the didactic mode of teaching. Several group learning activities were included, for example, group discussion, jigsaw and collaborative concept mapping.

2. Developing knowledge-building inquiry on Knowledge Forum. Knowledge Forum was implemented formally in the four classes in February. The teacher constructed the "Welcome View" with different topics for discussion and a view on assessment which had two sub-views, "Group Review Journal" and "Portfolio" (A view is a discussion area). The teacher designed the Knowledge Forum views to promote knowledge building while aligning the topics with the school curriculum. Students worked on Knowledge Forum as they generated questions, posed alternative theories and hypotheses, brought in new information, considered different students' views, and reconstructed their understandings. Problems emerging from the computer discourse were discussed in class.

3. Deepening knowledge building discourse, view management and rubrics. It is common that forum discussion tends to be scattered and fragmented so students need to be scaffolded to deepen their inquiry. Over time, the teacher worked with students and identified several sub-themes, note clusters, and questions that needed further inquiry. Clusters of notes were moved into "rise-above" views to help focus the discussion. Several weeks after beginning their work on Knowledge Forum, students were taught how to assess their own notes with the *rubrics* for depth of inquiry and explanation to help them write better notes.

4. Portfolio Assessment and knowledge building principles. For concurrent, embedded and transformative assessments, students were required to work in groups to complete an electronic "Group Review Journal" in which they had to evaluate the quality of the online discourse of their classmates in one of the "view" on Knowledge Forum. Also, each student was required to produce an electronic portfolio consisting of several best clusters of notes. For both group reviews and portfolios, students in two classes were given a set of principles as criteria for writing and assessing their notes whereas the other two classes just selected notes on their own. The teacher instruction for the knowledge-building portfolio was as follows (see Lee et al., 2006):

> You have to select four best notes together with a summary note that explains why and how you have selected these notes. Use the 'references' and 'scaffolds' and 'note reader' to write notes and complete the portfolio. One note is defined as a cluster of notes. The four notes selected will include notes posed by yourself as well as your classmates. You need to write a summary for each selected note. The summary note should explain the reasons for choosing that particular cluster. You need to organize the notes to help the readers understand the selected work, for example, give a theme of the selected notes and state which principle(s) can be identified. Use the guide on knowledge-building principles to help you with note writing and note selection.

Students were asked to submit the portfolio guided with a set of knowledge-building principles. A brief description is given of these principles adapted from Scardamalia's more complex system (see van Aalst & Chan, 2007): (1) *Working at the cutting edge*. This principle is related to epistemic agency, and it is based on the idea that a scholarly community works to advance its collective knowledge. For example, scientists do not work on problems only of personal interest, but on problems that can contribute something new to a field. (2) *Progressive problem solving/Ideas Improvement*. The basic idea is that when an expert understands a problem at one level, he or she reinvests learning resources into new learning. In the scholarly community, we often find one study raises new questions that are explored in follow-up studies. (3) *Collaborative effort/Community knowledge.* This principle focuses on the importance of working on shared goals and values in developing community knowledge. (4) *Monitoring personal knowledge/epistemic agency.* This principle is based on the idea that metacognitive understanding is needed for knowledge-building work. Specifically, it requires students to have insight into their own learning processes. It is similar to progressive problem solving in that it documents the history of ideas or problems--but now the focus is placed on metacognitive processes. (5) *Constructive uses of authoritative sources*. This principle focuses on the importance of keeping in touch with the present state and growing edge of knowledge in the field. To make knowledge advancement requires making references, building on, as well as using and critiquing authoritative sources of information.

Data Sources

<u>Analytic toolkit and database participation</u>

The Analytic Toolkit (Burtis, 1998), a software designed by The Knowledge Building Research Team at The University of Toronto, provides an overview of student participation using information on database usage. Several quantitative indices include: (a) Number of notes *written*, (b) Number of notes *read*, (c) Number of *scaffolds* used; scaffolds are thinking prompts (e.g., my theory, I need to understand) to guide writing and collaboration, (d) Words per note that might reflect quality of responses; (e) Percentage of notes *linked* to other notes, (f) Percentage of notes with *keywords* that can help others to search the notes, (g) Percentage of notes read and (h) Build-on trees indicating the number of notes in a discussion thread.

<u>Depth of inquiry and depth of explanation</u>

Computer notes on Knowledge Forum in a major inquiry thread were examined for depth of inquiry and explanation, based on cognitive research on problem-centred inquiry (Chan, Burtis & Bereiter, 1997) and an earlier study (Lee et al., 2006). Students' responses were coded on a 7-point scale to distinguish the levels of depth of inquiry, and students' questions were coded on a 4-point scale. These levels ranged from fragmented responses to paraphrasing information to inferences to explanatory inquiry. Inter-rater reliability is currently being established.

<u>Knowledge-Building Electronic Portfolios</u>

Students were asked to produce an e- portfolio where they identified incidents of knowledge building in the discussion; some were provided with principles depending on the condition. Typically the portfolio consisted of 2 components – (1) students needed to identify a cluster of notes that illustrated knowledge building and (2) they needed to write a short explanatory statement explaining why the selected notes illustrated knowledge building. We employed the scheme of portfolios (Lee et al., 2006) in rating the portfolios with a 6-point scale. For inter-rater reliability, 35% of portfolios was scored by a second rater and the inter-rater reliability was 0.90.

<u>Conceptual understanding</u>

To assess students' conceptual understandings, students in all classrooms were administered this writing task: *'Discuss ONE of the following statements: (1) Marine pollution is mainly caused by overpopulation, and (2) The root of the world problems, such as poverty, overfishing, marine pollution and deforestation, is the use of technology.'* All the students' essays were scored with a 7-point scale used in school assessment.

Results

Differences on Participation, Collaboration & Conceptual Understanding across Classes

<u>Participation on Knowledge Forum across Classes</u>

Overall participation and thread length. We examined students' overall participation in Knowledge Forum using The Analytic Toolkit. The average numbers of notes written were 13.18, 12.95, 7.78, and 6.73 for classes of High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. We also examined the *discussion threads* across classes. The ATK program generated four categories for size of thread – (i) small (2-5 notes), (ii) medium (6-20 notes), (iii) large (21-40 notes), and (iv) very large (>40 notes). The findings showed that the two kb principle classes had 75 small clusters, 40 medium clusters, 3 large threads and 1 very large thread (with 102 notes). The two no-knowledge-building principles classes had 69 small threads, 45 medium threads, and 1 large thread. The thread lengths suggest substantive interaction among students.

*Participation in Knowledge Forum (ATK Indices)***.** We examined student participation in Knowledge Forum based on several ATK indices including number of notes written, percentage of notes read, keywords, links, and revision. We first examined whether there were differences across classes for the whole period. A two-way MANOVA (principles x achievement) showed significant differences across classes, $F(8, 131) = 15.1$, $p < .001$. Univariate analyses showed that there were main effects for *knowledge-building principles* for the participation (ATK) indices of 'linked notes', $F = 4.36$, $p < .04$, 'No. of View Worked in', $F = 25.1$, $p < .001$, and 'Percentage Keywords', $F = 19.01$, $p < .001$ favoring students in the knowledge-building principles classes. We also obtained main effects for *achievement groupings* on the ATK participation indices of 'Scaffolds', $F = 7.64$, $p < 0.01$, 'Note Created', $F = 5.03$, $p > .03$, and 'Words per note', $F = 12.2$, $p < .01$ with high-achievers outperforming low-achievers.

*Changes and Growth in Participation (ATK Indices)***.** We examined whether there were increases over time in students' Knowledge Forum participation. We divided up the whole period of instruction into two roughly equal time intervals called Period 1 and Period 2 and computed the gain scores (Table 1). Two-Way (principles x achievement) MANOVA on gain scores showed overall significant differences, $F(8, 130) = 2.26$, $p < .05$. Univariate analyses showed that classes with knowledge-building principles had significantly higher *gain* scores than their counterparts on ‘Keyword’, F=10.1, p<.002, ‘Notes Linked’, F=8.15, p<.005, ‘Scaffolds’, F=7.96, p<.005, ‘Views Worked’, F=5.6, p<.002, and ‘Words per note’, F=4.74, p<.04. These results indicated that students in classes using knowledge building principle made more gains than their counterparts without the principles. As well, results indicated significant interaction effects (principles x achievement) for gains in ‘Keyword’, F=17.4, p<.001, ‘Notes Linked’, F=12.01, p<.001, ‘Percentage of Notes Read’, F = 11.72, p<.001, and ‘’Views Worked in”, F= 8.4, p<.01. Examination of mean scores indicated that the gains for classes using knowledge-building principles over their counterparts were mainly present for Low-Achieving students using principles. There were no differences in gains of ATK participation indices for achievement groupings. These results suggest that the effects of knowledge-building principles on gains in ATK participation were found mainly among low-achieving students (Table 1)

Portfolio Scores and Domain Understanding Across Classes

Portfolio Ratings. Students obtained portfolios scores of 3.67, 3.16, 2.27 and 2.04 for classes of High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. To make the differences more distinct, we grouped portfolio ratings into low-level and high-level portfolios for analyses. Two-way ANOVA showed marginally significant effects favoring knowledge-building principles classes, F = 3.75, p=.056. There were also main effects for achievement groupings, F= 19.4, p<.001 favoring high-achievers over low-achievers.

Table 1: Participation on Knowledge Forum for classes in period 1 and period 2.

		Words per note		No of Notes		No of Scaffolds		No of Views		No of Notes Read		% Linked Notes		% Keywords	
		P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Without Knowledge-Building Principles	Low Achieving	49	22.7	210	29	2.7	0.2	1.2	0.4	71.6	17.7	58	34	60	33
	High Achieving	55	92.3	361	161	8.7	5.5	1.4	1.5	175.7	114.3	65	65	44	46
With Knowledge Building Principles	Low Achieving	27	37.9	136	146	2.9	3.5	1.4	1.9	19.1	41.1	37	63	41	77
	High Achieving	45	164.9	320	202	6.0	5.9	1.6	1.6	99.3	74.3	57	51	55	47

Domain Understanding. The means of conceptual understanding scores based on the writing task were 5.3, 5.4, 5.4, and 3.6 for High-Achieving with Knowledge-Building principles, High-Achieving with no Knowledge-Building principles, Low-Achieving with Knowledge-Building principles, and Low-Achieving with no Knowledge-Building principles respectively. To examine differences across classes, a two-way ANOVA (principles x achievement) was conducted on writing scores. Results indicated there were main effects of knowledge-building principles favoring classes with principles $F(3, 135) = 10.2$ p<.01. There were also main effects of achievement favoring High-Achieving classes $F(3, 135) = 9.9$ p<.01. In addition, there was an interaction effect of principles x achievement, $F(3, 135) = 10.6$ p<.0.01 indicating the effects of the principles were more pronounced for Low-Achieving students using Knowledge-Building principles.

Relationships among Participation, Portfolios and Domain Understanding

We examined the relations between students’ ATK participation with their conceptual understanding for all students working on Knowledge Forum. Participation was measured by ATK measures. To simplify the presentation, the Analytic Toolkit indices were combined using factor analysis. Two factors were obtained, Factor One called *ATK Knowledge Building Inquiry Index (i.e. note created, scaffold, no. of note read, views worked in, percentage read, word per note)* explained 41% of the variance, and Factor II called *ATK Knowledge Building Visual Organization Index (keyword use, note link)* explained 16.7% of the variance. Correlation shows that quantitative and qualitative measures of knowledge building were related -- ATK Inquiry was related to portfolio (r = .53, p<.001); domain understanding was significantly correlated with ATK Inquiry Index (r = .22, p< .05) and with portfolios (r = .34, p< .01). A multiple regression analysis was conducted to examine the roles of knowledge building measures with prior academic achievement entered first, followed by ATK Inquiry Index, followed by Portfolio scores. Results indicated that academic achievement (Grade 8 scores) contributed significantly to domain understanding. When ATK participation scores were entered, there were small additional variances and the changes were not significant. When portfolio scores were entered, there was an increase in an additional 5% variance and the changes were significant (Table 2). These findings suggest that over and above academic achievement, portfolio scores contributed significantly to domain understanding.

Table 2: Multiple regression of academic achievement, participation, and portfolios on conceptual understanding.

	R	R^2	R^2 Change
Academic Achievement	.35	.12	.12***
Forum Participation	.36	.13	.009
Portfolio Scores	.41	.17	.04*

Characterizing and Tracking Individual and Collective Knowledge Growth

Collective Knowledge Building and Inquiry Thread

Quantitative Analyses. To examine further how students collaborated and how they made knowledge progress, we selected the largest note cluster, consisting of 102 notes of 19 students' responses and questions for assessing knowledge-building discourse. Knowledge building is the creation and improvement of ideas in which ideas are evaluated, revised and tested. Members contribute their problems and different ideas to the database driven by their personal as well as communal interests; they contribute notes and read, build on, rise-above and reference each others' notes. Using the system from Zhang et al (in press), analyses of notes in this large inquiry thread showed there were 79 conceptual comments (7%) in which 32, 24, 8, 16 and 1 notes can be classified into the following categories: (1) deep ideas, (2) stated alternative ideas, (3) questions for peers, (4) providing resource materials for inquiry, and (5) rise-above synthesis note.

We also examined whether the quality of students' responses improved over time. Students' questions were coded on a 4-point scale for depth of inquiry, and their responses were coded on a 7-point scale to distinguish the levels of depth of explanation. Results showed that there were 22 'depth of inquiry' and 94 'depth of explanation' notes. Analyses showed that 68 % of the notes were high-level questions (Level 3 - 4) and 32.6% were high-level explanatory responses (Level 4 - 5). A high level of questions may have the potential to trigger investigation and exploration and knowledge building discourse needs to be sustained by a deeper level of explanation. To examine growth over time, we broke down the notes further into two periods to see the changes in the quality of the notes (Table 3). Analyses revealed that there was a decrease in the number of low-level inquiry and explanation notes but an increase in the posing of high-level inquiry, and explanation notes in period 2. The results indicated that this group of students engaged progressively in a deeper level of knowledge building.

Table 3: Changes in depth of inquiry and depth of explanation over time for an inquiry thread.

	Depth of Inquiry		Depth of Explanation	
	Low-Level	High-Level	Low-Level	High-Level
Period 1	4	5	34	17
Period 2	1	10	15	31

Qualitative Analysis of Discourse. We further analyzed the largest note cluster (102 notes), identified in terms of the knowledge building principle of *Progressive Problem Solving/Ideas Improvement* to see how knowledge building evolved. Students' improvable ideas and growing collective knowledge can be illustrated in a schematic representation showing how new questions and ideas emerged. Figure 1 shows how a simple problem of overfishing evolved and grew with diverse ideas focusing on the controversy about using DNA (Use of DNA Technology as an alternative). The discourse continued to deepen and improve when students discussed DNA in terms of different aspects (ecological, ethical, economic), and led to further problems and solutions (Need to look for alternate effective solutions) and redefinition of the cause of overfishing (Who should be responsible?). Analyses of the discourse showed how a simple problem generated by students (overfishing) became an object of inquiry in this community. Here the schematic representation captures the evolution of ideas and knowledge progression in this community of inquirers as students opened up new issues and concerns. The note cluster illustrated how diverse ideas helped to spark progress and how the discourse evolved and improved with new problems and new ideas emerging with different students contributing to collective knowledge advances.

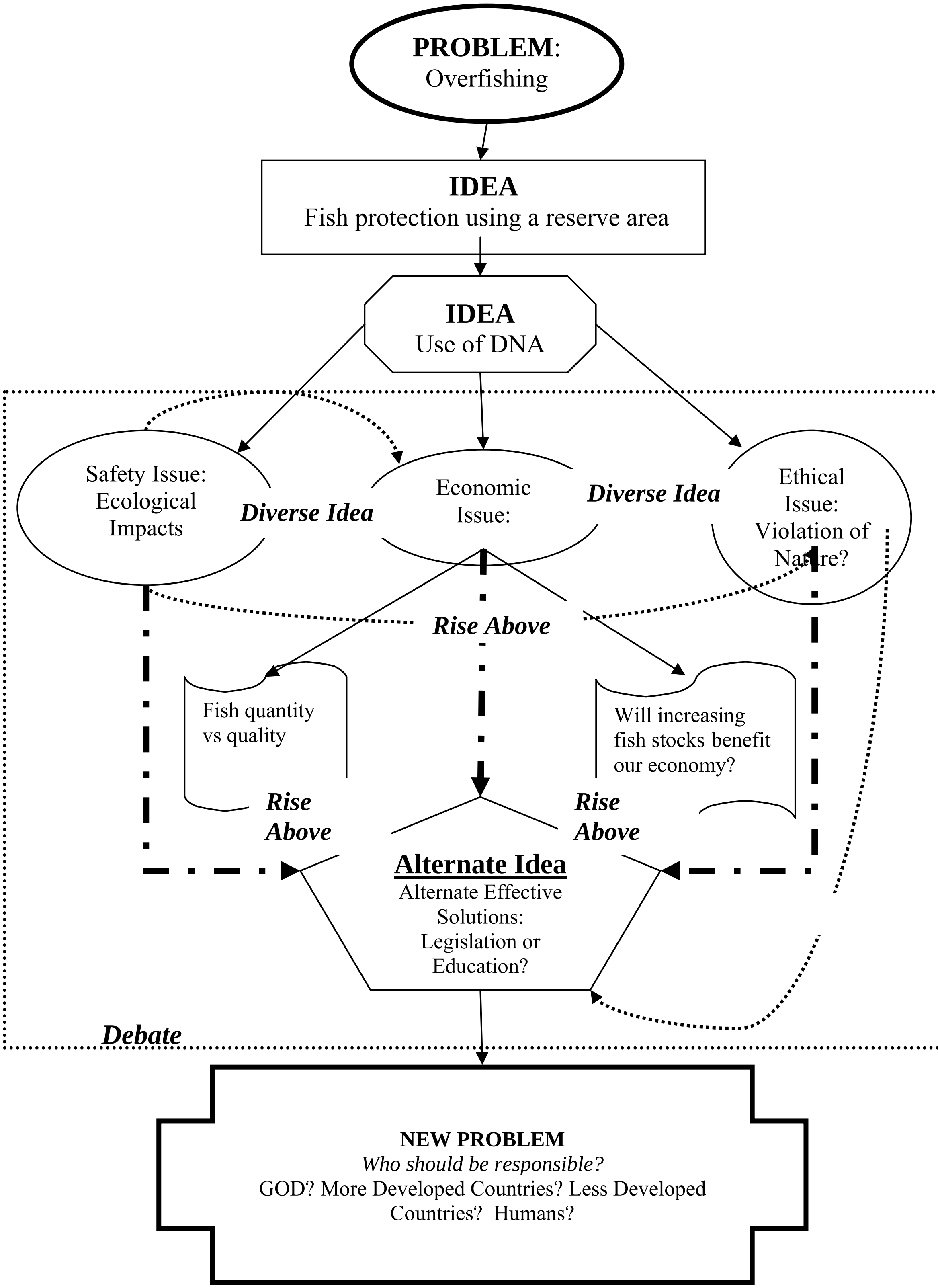

Figure 1. A schematic representation of emergent problems and ideas in an inquiry thread.

Knowledge Building Portfolio and Group Review

We included excerpts from a student's portfolio guided by knowledge-building principles to show how students reflected on collective knowledge building in their own discourse (Figure 2). Not surprisingly, many students chose the cluster on 'overfishing' illustrating knowledge growth. As the portfolio entry shows, the student documented the collective growth of knowledge in the community and explained why he thought it illustrated progressive problem solving; he examined different levels of contribution from his classmates using the rubrics and reflected metacognitively on his own contribution and understanding.

Sub-Theme Because of overfishing, fish stock fluctuates and they affect the fishermen and food supply badly in some developing countries. Our classmates suggest that we can try to apply DNA to the fish so as to change their DNA to let them reproduce faster to solve the problem. This cluster is discussing the advantages and disadvantages of using DNA to fish in order to discuss the [possibility] of using DNA to solve the problem of overfishing. *Progressive Problem Solving* This cluster consists of many notes, they always pose notes providing better [ideas] and further supplementary explanations of the information. They discuss all the advantages and disadvantages of using DNA to [see if they] can solve the problem. They give further room for readers to think about…. For example [1] Changing DNA isn't a solution. This classmate has raise[d] the disadvantages of changing DNA at first, after reading other notes, he even [found] other notes [dealing with] the disadvantages of changing DNA. [2] About the disadvantages of changing DNA of the fish. Classmates make good use of raising questions to improve their theory. Raising questions continually can help to improve ideas and give further supplementary explanations of the idea….Although this is a good cluster, there are still some good and bad questions..…Example of good answer: [3] DNA~Good/Bad This note has 2 features, he [describes] a possible situation of changing fish DNA [and] even shows his personal view of changing DNA. However, he can make a further explanation [and] his prediction would be better….*What I have learned.* From this cluster, I have learned there are many methods to solve the problem of overfishing not just reducing the population….

Figure 2. An example of a portfolio notes showing use of principles and rubrics.

Discussion

We have designed an assessment approach to characterize and to foster collective knowledge advances in Knowledge Forum. Primarily we turned over agency to the students, asking them to assess the community's knowledge advances in the computer discourse, using rubrics, group reviews and portfolios. Our findings indicate that the students provided with knowledge-building principles performed better than those without principles on ATK participation, portfolios and domain understanding; the effects were more pronounced for low achievers than for high achievers on several measures. Portfolio scores predicted domain understanding over and above the effects of academic achievement. Discourse analyses and portfolios helped characterize knowledge building as progressive inquiry and idea improvement. These analyses also provide insights about how such concurrent, embedded and transformative assessment might scaffold both collective and individual advances.

Characterizing and Fostering Knowledge-Building

We have replicated and extended earlier findings on roles of knowledge-building portfolios for characterizing and fostering knowledge building (Lee et al., 2006; van Aalst & Chan, 2007). The present results showed the roles of knowledge-building principles and portfolio assessment on knowledge building and domain-related understanding. Consistent with earlier work, we found that the knowledge-building portfolio is a useful artifact to capture and *characterize* collective knowledge advances. Each portfolio is not an *individual* work – it is based on the *collective* efforts of students tracking their own growth in their understanding of certain ideas. These portfolios have pedagogical benefits and they might also help address theoretical issues of how we can assess collaboration and group cognition (Stahl, 2006). Primarily, knowledge-building portfolios consisting of contributions from various members in the community might help to illuminate the nature and dynamics of knowledge building focusing on idea improvement. More importantly, these e-portfolios that assess and document students' growth over a sustained period of time are somewhat different from the common approach of analyzing collaboration based on minute-to-minute moves. The way these portfolios show a growth trajectory over time may provide another approach for examining how new ideas can be *created, refined and sustained* in collaboration.

Our results indicated that students using knowledge-building principles to assess their own and community work performed better than those without the help of knowledge-building principles. These findings suggested that helping students to recognize knowledge building episodes and to explain them might be important to help them engage in more knowledge building. When they browsed the database they were better able to identify good examples and become more metacognitive. Students engaged in examining their own and community knowledge advances might be more likely to engage in co-construction and thus developed deeper understanding of domain knowledge. This study examined portfolios and we refined their use, helping students to assess both individual and group contributions using rubrics of depth of inquiry/explanation and group reviews. We noted that students made reference to individual notes using rubrics as well as group progress in portfolios. Students discussed, evaluated and rated each of the exemplary notes as well as the cluster as a whole and considered knowledge building in the context of how different notes or ideas improved collectively in sustaining knowledge building discourse. Portfolio assessment extended with rubric evaluation helped the students to identify individual work and community's progress as well as to help them reflect metacognitively on their own understanding

Tracking Knowledge Growth in the Community

As knowledge building focuses on improvable ideas, this study also provides some ways to show how we tracked student growth. ATK indices showed that students made gains and those using the principles made more gains over time. We also examined whether students had made knowledge advances focusing on the analyses of a large inquiry thread. We rated each note in the cluster using rubics of inquiry and explanation so as to explore the relationship between individual understanding and collective knowledge building. Rating of the notes suggested that students wrote deeper questions and explanations in later parts of the discourse compared to earlier phases.

We also attempted to employ a schematic representation to trace idea improvement episodes in online discourse. Findings show that the inquiry thread that we have examined consists of a large proportion of high-level inquiry and explanatory responses. Conceptual comments could generate more ideas, sustaining the inquiry for alternative and diverse ideas for reaching a deeper level of understanding for the community (Zhang et al., in press). Analysis indicates that students scaffolded by knowledge-building principles could generate more high-level inquiry and explanatory questions and responses. The schematic representation we have produced illustrates aspects of how new ideas and new problems emerge in the knowledge building community. One simple problem of overfishing aroused immense interest in students who worked on the idea of using advanced technology as a solution. In the event of debating over the feasibility of changing DNA of fish, new ideas emerged and new problems came into existence as "Who should be responsible? God? More developed countries (MDCs) or Less developed countries (LDCs)? Or Humans?" Questions centred on problem-based inquiry would engage students in knowledge-seeking inquiry. They formulated questions around problems; they began to identify difficulties with their understanding, and constructed explanations to guide their inquiry.

Knowledge Building and Student Diversity

This study also showed that, guided by knowledge building principles, students, both high- and low-achievers, engaged in productive knowledge practices. Most interestingly, there were some interaction effects indicating that knowledge building principles had more effects for students in Low-Achieving classes on gains in participation and domain understanding. This extends our earlier work, suggesting that knowledge building principles and portfolios can benefit both students of high- and low achievement levels. These findings are consistent with research on higher-order thinking for low-ability students (Zohar & Dori, 2003) and recent work on knowledge building for high and low achievers (Niu & Van Aalst, accepted).

Many teachers believe knowledge building and other forms of high-level instruction would be difficult for low-achievers. The contextual background in Hong Kong, with streaming of students into high- and low-ability groupings, provided us an opportunity to examine whether knowledge building principles could be applicable for low achievers. We did find that high-achievers outperformed low-achievers on portfolios, possibly due to the more complex nature of the task. Nevertheless, for Forum participation, we found low-achievers gained more than high-achievers when they were scaffolded by knowledge-building principles. We even found that low-achievers benefited more than high-achievers on domain understanding when provided with principles. Such findings are interesting because often teachers will see student ability as barriers. Knowledge building focuses on collective work rather than individual competence. Similar to other cognitive models, such as fostering a community of learners focusing on students as teachers (Brown & Campione, 1994), the emphasis on collective progress in knowledge building might provide another pedagogical model to help work with students of diverse abilities.

In sum, we extended our earlier work examining portfolio assessments and demonstrated more clearly the roles of knowledge-building principles using group review journals, portfolio and rubrics. Students constructed their collective understanding through analysing the online discourse, and group review journals and portfolios were used to mediate the interaction between individual and collective knowledge advances. Our study has shown that concurrent and embedded assessments are useful for both high- and low-achieving students when given appropriate scaffolds. When students are provided with the principles, they became more aware of what productive discourse entails; the principles are scaffolds for their knowledge-building progressive inquiry. How individual and collective agency can be supported by assessment in the knowledge-building community are important research issues that need to be investigated further.

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Creativity, Collaboration and Competence: Agency in Online Synchronous Chat Environment

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Abstract: Agency is potentially an important concept for CSCL as researchers think about the effectiveness of online learning environments and the ways they encourage groups to take active control of their learning activities. This paper reports on several sessions of mathematics problem solving in the VMT Chat environment. The VMT Chat is a synchronous chat and whiteboard space for students to collaboratively define and work on problems that are open-ended and that encourage students to define the questions themselves. We draw on the anthropological, psychological and sociological traditions and their concept of agency in order to produce a robust analysis of several segments of student work in the VMT Chat. Our analysis suggests that there are structural features to the VMT Chat environment that encourage "agentic behavior" on the part of students. This has important implications for learning and the structure of pedagogic activities.

Introduction

This paper looks at the mathematics problem-solving behavior of students in the Math Forum's VMT-Chat environment. The VMT project is a project that is attempting to provide an online synchronous environment for small groups of students to work on math problems together. The project has not only designed a whiteboard/chat environment for students to work in but also does research on various aspects of online collaborative problem-solving.

Computer supported learning comes in many forms and hybrids. There is the notion of computer supported collaborative learning (CSCL), computer-supported community-based learning (CSCBL), and so on. Enactments of such learning opportunities apply to students from primary school to university; they refer to formal and informal learning such as after-school and community centre programs; and to online, face-to-face or to some blend of these. In all cases the one constant is the use of computer tools and artifacts to create activities for intellectual exploration and promotion of social interaction (Stahl, Koschmann & Suthers, in press). These activities are designed to engage students in learning through jointly negotiating and planning how to proceed, generating questions and exploring possible problem solutions together, in the process modeling and scaffolding learning for each other. In short, instruction and learning is viewed as a group initiative and not a teacher lead effort, hence, supporting and sustaining productive interaction is crucial. A major design consideration should be the promotion of students' *agency* over the processes by which knowledge and ideas are created and improved, sometimes referred to as *epistemic agency* (Scardamalia, 2002). In fact, Scardamalia and Bereiter (1994) describe the release of agency as a guiding principle in the design of their knowledge building communities (KBC). But what do we know about this phenomenon? How do we know that our computer supported learning environments are harnessing (marshalling) the potential of the powerhouse individual and group attribute? What does agency look like when we take a close view of the interactions between individuals? What can we learn from a close examination of this phenomenon that may help design future collaborative environments (both online and face-to-face) or may help promote the development of agency in less agentic groups?

In this paper we use the concept of agency to frame our analysis of some recent data in the VMT-Chat environment. We are interested in thinking about agency as a concept because we would argue that students and groups with a greater sense of competence and self-efficacy will have the potential to make greater progress in their mathematical learning. Agency as a concept helps us understand the relationship between structural (including technological) constraints and human action. This in turn can inform our thinking about the strengths and weaknesses of this kind of online project for a sense of identity, competence and self-efficacy.

The Research Setting

Virtual Math Teams (VMT) is a five-year NSF funded project starting in Fall 2003 designed and run by researchers at Drexel University and *The Math Forum* (http://mathforum.org). Its aim is to create an online environment to promote and support the knowledge building and math discourse between groups of individuals who enjoy doing math but do not generally have opportunities to meet and work with like-minded learners. To achieve these goals, VMT researchers designed a software environment called *VMT-Chat*, which provides chat rooms for small groups to meet on the Web to communicate about math and engage in joint problem solving, mediated by a whiteboard, chat logs and associated referencing pointing tools all archived for future referrals. By bringing learners together, the VMT environment and tools challenge participants to engage in collaborative activities that call for jointly negotiating goals, meaning of the shared tasks while constructing problem solutions (e.g., explaining and defending own ideas) and jointly regulating the group's progress.

Structure/Agency

Before we start let us briefly situate agency within the CSCL literature. Most notably, the notion of agency, specifically epistemic agency, has been the focus of work conducted by Marlene Scardamalia and her colleagues (e.g., Scardamalia & Bereiter, 1991; Scardamalia, 2000; 2002). In the course of observing students' use of CSILE and Knowledge Forum, she coined the term epistemic agency to describe the acts of initiative taken by students (very young in some cases) to present their ideas and negotiate a fit between personal knowledge and those of others "using contrasts to spark and sustain knowledge advancement rather than depending on others to chart that course for them." (e.g., Halewood, Reeve, & Scardamalia, 2005, p.2). In taking on the responsibility for aspects of learning, such as, goal setting, motivation, evaluation, and long-range planning, students demonstrate their epistemic agency. As such, Scardamalia (2000) views epistemic agency as one of the two major components of productive engagement. From the collaborative learning perspective, epistemic agency implicates the students' willingness to see themselves as a member of a community, hence their community identity. Which, along with epistemic agency is seen as mutually constituting the students engagement in community discourse (Brett, 2002). We will return to this line of reasoning below.

As a particular case of the larger Western pre-occupation with determinism verses free will, sociology and the social sciences since their inception have tried to think through the relationship between structure and agency. One interesting perspective on the structure/agency binary is the thought of the British sociologist Anthony Giddens. For Giddens structure is a product of the pattern of practices that social actors engage in. Therefore structure is emergent out of human activity. Further there are different levels of structure that emerge out of different forms of human practice, signification, legitimation and domination. Signification has to do with the production of meaning, legitimation the production of moral order through norms and values and domination of course is produced through the exercise of power (Giddens, 1979; 1984).

These above types of structures are produced by human activity but once they exist they then work to constrain future human action. Therefore the structure produces patterns of activity that, in the French sociologist Pierre Bourdieu's terms, becomes habitual action structured through activity of the past but then used to structure and classify future activity as well as things in the world. This dialectic used by both Bourdieu and Giddens is one way to overcome the primacy of either structure or agency and succeeds in showing how dialectically they are the product of each other. Giddens adds a further dimension to structure and that is that people are conscious of their practices and so they engage with structure in a self-conscious effort to reproduce it or change it. So that there is a reflexive quality to agency. While Bourdieu is also aware of this self-consciousness he is much more interested in the way that most human practice is habitual or semi-conscious. Bourdieu is aware of the fact that social actors often have a "strategy" for "playing the game" of life, but they are also often in his mind "shooting from the hip" (Bourdieu, 1990).

Giddens and Bourdieu's understand of the relationship between structure and agency is very useful for our analysis of the VMT. From the beginning the VMT project has been a design-based development project. And so the practices of students using earlier generations of the chat environment (even starting with just AOL IM) influenced design decisions for future environments. The goal of the design team has been to enable future activity that the participant sought to engage in and to constrain activity that seemed to detract from the productive working together of the problem-solving teams. But further the activity of the participants themselves solving a problem and interacting with the technology begins to build up a kind of small group structure that then carries through to the remainder of the session and may influence future work sessions of the same group. So looking at the micro interactions of structure and agency for a particular problem solving team can help us understand how collaborative problem solving works in this environment and how to further support the team work.

Creativity/Imagination/Identity

In a major article on agency, Emirbayer and Mische (1998) offer a critique of the Giddensian and Bourdieuian position. Essentially they argue that the focus of Bourdieu and Giddens is too much on structure and the production of habitual action and not enough on the creative emancipatory potential of human agency. The conflict between Giddens and Bourdieu on the one hand and Emirbayer and Mische on the other represents a very important paradox in social theory. On the one hand social theorists have to account for the dramatic patterning of human action and the way much human behavior can be predictable. On the other hand one must also account for the production of new culture and the process of cultural change. These two realities are difficult to contain within the same theory and theorist tend to emphasize one pole or the other.

Our hope is to view agency as an act of creativity, which draws these two perspectives closer. Thus our definition of creativity does not fit with the standard psychological definition. We would argue that much of social life is constrained structures that themselves are the product of past action both conscious and habitual and that these constraints are something that social actors must indeed face. But on the other hand as we will discuss below there are creative potential for social actors to engage with those structures in new ways. We feel that online services like the one the VMT is constructing in fact facilitate the creative and imaginative when students attempt to deal with the constraints around learning math.

Emirbayer and Mische want to emphasize the creative dimensions of human agency. For them these dimension have a future focus and are tied up with creativity, imagination, improvisation etc. This notion of identity dovetails nicely with the work of Bandura (2001) and Dorothy Holland and her colleagues (Holland et al., 1998).

Bandura's (2001) model of agency offers a way to take the above characterizations into consideration and describe them in a developing comprehensive theory. This theory articulates a model of agency composed of four key components, which account for cognitive, affective and psycho-social characteristics: (1) intentionality, (2) forethought, (3) self-regulation, and (4) self-efficacy. Agency is more than a mere self-regulating activity, rather it is involves planning, reasoning, monitoring progress, and reflecting on beliefs about one's capabilities. Viewed in this light, agency can be both a quality of actions produced by an individual as well as the interactions produced by a group of individuals. In other words, when working collaboratively as a group, these four characteristics can be transposed into jointly shared actions or enterprise. As a collective production, intentionality is jointly negotiated, forethought is jointly shared, members engage in co-regulation of progress, and the group develops a sense of co-efficacy or belief in a collective capability (Charles & Kolodner, submitted). In this manner self-regulation and self-efficacy become more than cognitive acts, but social and culturally driven ones as well, in fact, Bandura claims that self-efficacy promotes a "prosocial" orientation. Taken as a whole, these collective productions implicate changes to identity – possibly shifts from individual identity to group identity (i.e., team member or even member of larger discipline-specific member).

According to Holland et al. (1998), agency is intimately related to, and mediated by, identity. In turn, identity is shaped through activity in social practice and is the principle way in which individuals come to "care about and care for what is going on around them" (Holland, et al., 1998, p. 5). Thus agency and identity are mutually constitutive systems that play out in two forms: (1) acts of improvisation; and, (2) acts of self-directed symbolization. Improvisations are actions that are independent of structural or cultural constraints. They are mediated by one's "sense and sensitivities," what we might also describe as awareness of perceived need to act. Symbolization refers to the human ability to create imaginary worlds, "*figured worlds.*" It allows learners to participate in activities and use language, signs and symbols, to organize themselves and others in exploratory ways. What Gee (1992) refer to as the disposition to engage in "pretending."

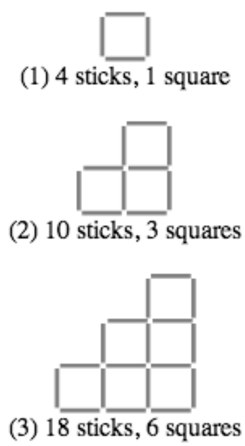
Taking all these theoretical ideas into consideration, we will now move to the analysis of VMT data in an effort to show some of the creative moments of agency and how the VMT system creates an opening for students who are constrained by the norms of classroom mathematics to really open up and think about and practice mathematics in new ways.

VMT Data Analysis

The data snippets that we are about to look at are part of a set of conversations that a group of four students[1] engaged in around a series of open-ended problems. Six other similarly composed groups participated in this pilot study. We selected this group because of their attendance record, which allowed us to better track the progress due to individuals' agency, or lack therefore. The students meet for the first time in the chat environment, thus had no prior histories together. They had four one-hour sessions working with and getting to know each other over several weeks. The full transcripts of these conversations are very long. Here we look at just a couple of moments in this much bigger problem solving activity. Before moving forward, we briefly describe the assigned tasks the students focused on during the featured segments.

The Assigned Tasks

The "stick" challenge starts with an identification of pattern and construction of mathematical rules to describe the growth of a graphical pattern. For example, in the first session, students are provided with the representation below (see Figure 1) and asked to account for the growth in numbers of sticks used and squares created when N=4, N=5, and so on. In the second session, which we discuss, the students continue to work on this problem, but this time they are asked to extend their reasoning to include creative problem solving such as constructing other mathematical problem related to the problem with the sticks. For instance, they are asked to consider other arrangements such as triangles, hexagons, 3-D figures, like cubes with edges. As well, they are asked to analyze their patterns using different methods such as induction, recursion, graphing, tables, and so on.



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

Figure 1 – Example of the initial sticks task.

A typical example of what the whiteboard looks like at the end of session 1, and the beginning of session 2 is below (see Figure 2). From this point, students negotiate the meaning of concepts such as recursion, coordinate drawings of graphical representations and jointly construct mathematical formulas to account for the patterns they identify. (NB. the formula on the whiteboard is ((1+N)*N/2 + n)*2).

[1] Due to the design of the study, the participants were anonymous therefore we do not have exact ages for the individual students but they were approximately 12-14 years old. This design also ensured that the students had no prior history together.

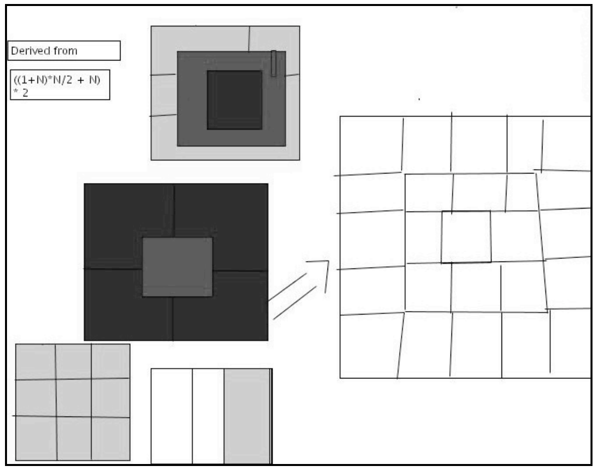


Figure 2 – Segment of Team B's whiteboard, Session 2

The grid world challenge starts off with a situations where the students are asked to imagine they live in a world where one can only travel along the lines of a grid - for example, driving in a city like Manhattan or Philadelphia. They are asked to construct solutions for the shortest path between two points, A and B, remembering to stay along the grid. The are then asked to extend this reasoning by creating relationships between points when A is at (x1, y1) and B is at (x2, y2). For instance, a solution used by Team 5 in their fourth session (see Figure 3). Such problems encourage students to define and calculate grid distances, define analogs to shapes defined in Euclidean geometry. In doing so, students engage in reasoning with mathematics as a creative enterprise.

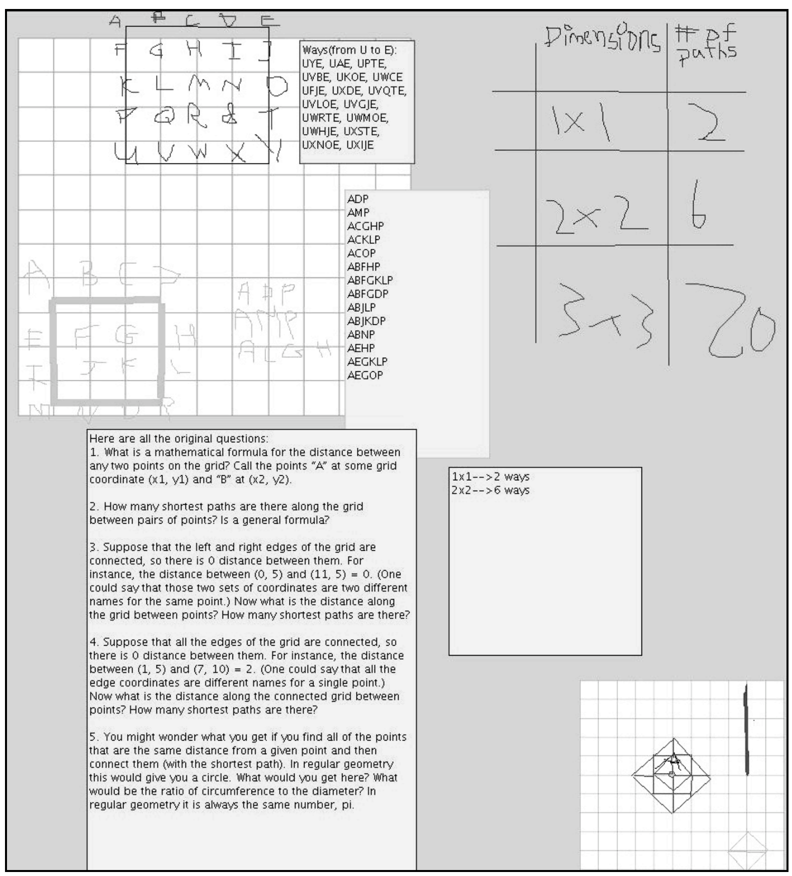


Figure 3 – Snapshot of grid world whiteboard.

Case Studies

We believe that synchronous online chat environments, designed specifically to engage participants in learning, are special in that they require individuals to take on certain kinds of agency, which may have implications on how and why they learn. This agency is demonstrated in a variety of ways, most noticeably in student's self-efficacy, in their intentionality related to negotiation of the goals to be achieved, and in their co-regulation of the progress of activities leading to the attainment of those goals.

This is different from traditional classroom learning (and perhaps other forms of online learning such as teacher lead e-learning), and even perhaps what we generally see in face-to-face small group problem solving because of the unique features of the environment. These features include purposeful equalizing of positional identities (true sharing of authority because of the anonymity of participants – histories are developed within this setting), the linear nature of the conversation (only one voice at a time), the "engraved" nature of time (conversations and artifacts are archived and retrievable), and the cultural practices that are necessitated or made possible by the technological tools (e.g., pointing back with the referencing tool; waiting to respond until after reading a posting). We propose that to function within these structures may require or encourage/promote a certain sense of agency.

Take the following excerpt as an example. It is the second of 4 sessions with three students (Quicksilver and bwang8 and Aznx) working on a math problem involving sticks. In the beginning it is clear that Quicksilver and bwang8 are capable of working together to find the solution to the problem presented. They engage in small linear acts of building on the others ideas or questions, each time reflecting an interplay of planning the next step (intentionality) and regulating how it fits the intended goal (i.e., solve the problem). What comes out of these small linear actions is a sense of shared achievement and moving forward. For others, such as Aznx, however, it appears that their sense of agency may be related to time to reflect on the archival structures of the environment.

591	Quicksilver	08.04.03:	you guys can add on
592	Quicksilver	08.04.08:	i just put the basic
593	Quicksilver	08.04.20:	Maybe share our results?
594	Aznx	08.04.53:	We technically had the same result.
595	Quicksilver	08.05.07:	Whaddya mean?
596	Quicksilver	08.05.21:	oh as yesterday?
597	Aznx	08.05.31:	Yeah.
598	Aznx	08.05.36:	And today.
599	Quicksilver	08.05.40:	Still...
600	Aznx	08.05.43:	Well today was really a discussion.
601	Quicksilver	08.05.46:	we should say that'

His general contribution to the group changes significantly once he positions himself as someone who makes observations such as the one above and has capabilities the group will need (i.e., he is good with words). In this occasion he expresses a high degree of self-efficacy and takes on an active role in constructing the artifact to be posted on the group's wiki.

609	Aznx	08.06.55:	Wait, who is submitting?
610	Aznx	08.06.57:	bwang?
611	bwang8	08.06.59:	tell them the intervals between levels

612	Aznx	08.07.06:	or quicksilver, or me?
613	bwang8	08.07.08:	sorry, i am bad with words
614	Quicksilver	08.07.14:	So am i
615	Aznx	08.07.15:	Not to worry.
616	Aznx	08.07.21:	We should write it out
617	Aznx	08.07.22:	here
618	Quicksilver	08.07.24:	Aznx to the rescue lol

Here is a second example from a group of students working on a different problem called grid world where students explore the geometry of a world where everyone must always follow the grid and there is no movement in the space that is off the grid. In this example "meet_the_fangs" and "dragon" have been working on the problem and developing some more sophisticated ideas about how to solve the particular problem of navigating the grid. "Estrickmcnizzle" and "gdog" were quite quiet for a long time when they finally interrupted the interaction with "estrickmcnizzle's" comment "we aren't getting anything done."

218	estrickmcnizzle,	20:50 (19.05): we arent getting anything done
219	meet_the_fangs,	20:50 (19.05): any suggestion?
220	estrickmcnizzle,	20:51 (19.05): i dont know, maybe just a more simple problem
221	estrickmcnizzle,	20:52 (19.05): less time consuming
222	gdog,	20:52 (20.05): drop the questoin
223	dragon,	20:51 (19.05): I think I know the answer...
224	gdog,	20:52 (20.05): more simpel one that i can understnad plz :)
225	meet_the_fangs,	20:52 (19.05): ask the mod to put up thequestions
226	meet_the_fangs,	20:52 (19.05): or we can do the summer one

Estrickmcnizzle's comment opened the group to thinking about the problem, and possible solutions, differently. It also gave the two quieter members of the group different jobs to do in relationship to posting the group's solution and how to share those results with the VMT staff and other groups.

Discussion

Clearly, the unique features of the online chat and whiteboard tools influence the patterns of practices engaged in by the social actors in VMT, thus implicating the structure emerging from this social setting. In this case the structures produced through the interactions of the students involved act to negotiate and co-regulate the production of meaning, the norms and values of the jointly created figured world, as well as the exercise of power, what Giddens refers to as signification, legitimation and domination respectively.

Traditionally the structure of the classroom, and what agency is expressed, are transposed from other similar sittings. Thus the constraints of past experiences may significantly limit what actions students take. In these relatively new online chat environments, however, such structures, if they exist, are borrowed from purely social experiences (e.g., chat rooms, blogs). Thus in many cases the signification and legitimation are all newly developing practices, and domination may not play a central role – at least not initially. Furthermore, with malleable structures there are malleable constraints, which offer greater opportunities for improvisations – the creative and unexpected making of dialogic turns. When we think of how these adaptive structures relate to agency in collaborative activity, we see collaborative group learning in a different light.

In the examples we've given you, we show that learning can be described as creative and improvised acts of agency – both individual and collective. The online chat and whiteboard environment appear to free the students from the other kinds of social constraints that exist in their worlds and give them opportunity to make creative problem solving decisions. It may also be that the types of students who are drawn to these settings are those that more familiar and comfortable with these newer social constraints. In the first example it is a problem that asks students to think about the relationship between the numbers of sticks one uses to make squares and then what happens when one puts those squares into different shapes. This is a very open-ended kind of problem that might be very intimidating in a typical classroom setting. But in the VMT chat the students are creatively playing off of one another in order to make some insights about the sticks and squares problem. They are able to take up a sense of agency as they play with the problem and help to define what new questions to ask. In the second example we see one pair of students having the agency to stop the more "knowledgeable" students and ask them to engage in a set of questions they can all understand. Again this is a remarkable breaking with traditional classroom norms.

Pulling back, agency, in some respects, requires individual and collective actions. When individuals begin to interact in coordinated or shared states of intentionality, forethought, self-regulation and self-efficacy, there is the converging and emergent values and beliefs – sensibilities and awareness of interdependencies, and interconnectedness. Interdependencies are characterized by the development of mutual accountability and co-regulation – socially negotiated responsibilities, expectations and standards from which everyone is evaluated, including oneself. Interconnectedness is characterized as the development of mutual benefit – awareness of distributed capabilities, i.e., that everyone does (may) benefit from the noticings (attending), problem solving, reasoning and reflections of individuals; and the awareness of the development of a shared culture, resources and social history – ways of asking questions, producing solutions to the math problems. So again in the second example the students work together to define the questions they want to answer. There is a pressure to collaborate and a scaffold to encourage all to speak and play with the problem.

Returning to Bandura's (2001) proposal that group achievement are the products of, and produced by, the interactive, coordinated, and synergistic dynamics of members' transactions, and not merely by the individual's intentions, knowledge, and skills, recall that transactions are an ongoing dynamic process that brings about a state of interconnectedness and interdependency (transformational process). Thus, because of transactional dynamics, the interconnectedness and interdependency of individuals with shared beliefs in their collective power and efficacy can result in the perceived group-level emergent property described here as a sense of collective agency. In the brief examples shown, we see the interplay between individual and group. The VMT chat is a space that in some senses is liberated from the social constraints of a physical space. With virtual bodies and minds students have the tools to play off of each other and enjoy the creativity of that play. This potential for a open and free interaction encourages individuals to be agentic, but it also encourages the group to feed the individuals and to get students to act like mathematicians, asking questions of the worlds they have created.

Conclusion

When one looks at the larger passages of interaction one sees this dance of creativity and agentic behavior more clearly. Our brief examples have been drawn from larger sessions where groups of students work in 3 or 4 sessions of about an hour to two hours. These sessions largely involved the same participants and so a sense of community was created among the students who worked together. In this larger set of data one can really see the ways that groups take up problems, define them, attempt to answer them, explain their answers and move on to new problems.

The VMT chat then has created something very unique. It has created an online world where students take control, define problems, respond to each other and then attempt to answer these problems. In this way they look more like professional mathematicians, in training, than students in a classroom. We would suggest that the VMT Chat environment has the potential to overcome the structural constraints that one might see on social action from a Giddensian or Bourdieuian perspective. These constraints are to some extent avoided because the environment creates a collaborative space that can be defined by the participants and does not readily reproduce the hierarchies or power relations in traditional school settings. Though it can also be argued that eventually a certain kind of social network will develop based on the social interactions possibly producing hierarchies and power relationships.

Further, the social action that students engage in, in the VMT environment, creates new structural realities for their further work in that space. As Giddens suggests there is a self-conciousness to this social action and the social action that is encouraged is creative and draws upon the participants' imaginations to see knowledge production as a fun, interesting and possible activity for ordinary people. Further understanding how to harness this agentic behavior and leverage it for deeper learning will be a next step for this research.

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Towards a Community Incubator: The ICAP Design Framework for Social Constructivist Educational Designers

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Abstract. This paper highlights the often-mentioned mismatch between the more social constructivistic oriented pedagogy and the traditional instructional design model. Such a framework is important as a design process relevant to the work of CSCL. Any attempt trying to apply the traditional Instructional Design approaches (e.g., ADDIE) to social constructivist learning in CSCL contexts such as the community of learners approach is fundamentally flawed because the two stem from different assumptions of knowledge and philosophies of pedagogy. Based on a modified Activity Theory, we propose the ICAP (Identity, Community, Activity and Personal) design framework for social constructivist oriented approaches to educational design as an alternative to this mismatch. A case example of how ICAP is applied to designing a postgraduate degree program is reported.

Introduction

It is now widely acknowledged that most existing instructional design models are not suitable for designing instruction which is based on the social constructivist approaches (Jonessan, 2000; Reigeluth, 2004). Traditional instructional design models regard the role of the teacher as that of an expert and knowledge being transmitted from the expert to the novice. This is accomplished via carefully packaged or designed instructional activities. The focus is on the teacher and the content to be delivered. Under this type of conception to learning, it makes sense to analyze the content and the task involved in the knowledge to be taught and design instruction accordingly to deliver the knowledge. However, recent proliferation of learning as knowledge construction, place students are at the center on the stage, and the process of learning becomes important. Contents or knowledge is therefore not as prescriptive or definite as it used to be. Meanings are constructed by individuals and they can be different from that of the teacher. Analysis of the content of the tasks, therefore, does not really inform the design of this type of instruction. Furthermore, the community-based approaches emphasize the social interaction dimension of learning where individuals learn in the context of a community of learners or practice. The traditional wisdom of analyzing the content and designing the instruction become almost irrelevant in this context.
In this paper we propose the ICAP design framework as an alternative to the predominant educational design processes known as the ADDIE processes (Chen, Hung & Wang, 2006). Social constructivist approaches, which uphold the importance of collaboration among peers, authenticity to learning activities and the emergent nature of knowledge construction, are suffering from an apparent lack of a design framework. In Chen, Hung & Wang (2006), we argue for congruency between learning theories and their epistemologies and the design process.

Activity theory is one conceptual framework which can tease out the activity processes within social constructivist interactions. Activity theory provides a framework or community-based learning where learners and experts can co-work together, establishing shared knowledge, in authentic tasks through the use of appropriate technologies, learning resources, and tools. Note that there are a number of variations to Activity Theory. The variation of Activity Theory in this paper is our re-conceptualisation based on Cole and Engeström's (1991) proposal. Activity Theory (to be introduced below) and the above-proposed four dimensions constitute a powerful way for designing community-based learning activities.

Activity Theory

Cole and Engeström (1991) conceive an activity as follows (see Figure 1). This activity system below encompasses Wenger's notion of language, implicit and explicit, rules, roles, and tools. However, language is not explicitly reflected in the activity structure but it is core to the dialog and interactions surrounding the constructs of any activity. The notion of dialog through language is exemplified through the Bakhtinian notion of contextual genres and voice peculiar to the specified community of practice. Complementing the Vygotskian and Bakhtinian perspectives, genres and language peculiar to that community would become internalized through dialog.

An "activity" is undertaken by human actors motivated towards an object (or goal) and mediated by tools and the community. Activities are distinguished from each other according to their objects. It is the object that shapes the actions of participants within that particular community, and over time, forming the dispositions and identity of the members of the community. Broadly speaking, if the *object* of a profession is to make advancements in a particular domain, then the actions within that community are engineered towards achieving that particular goal. The *division of labor* (or roles) and *tools* involved in mediating toward that goal assists in shaping the identity of those members who use the tools and perform their roles and functions. It is the transformation of the object into an outcome that motivates the existence of an activity. In short, the tools, rules, and roles within the activity system mediate the actions and processes by members in the community. The subject exists in a community which comprises of other individuals and subgroups that share the same object. From a Vygotskian perspective, these (psychological) tools play a crucial role in identity formation. The relations between the subject and community are mediated by the community's collection of mediating rules such as explicit and implicit regulations, norms and handbooks that encourage and constrain actions and interactions within the activity system. Thus, these tools (including the communities' signs and symbols) and rules (experienced as the participants engage in their functions) become internalized over time and form part of the learners' identity. Identity is a crucial part of the design process in lieu of content which is the emphasis in ADDIE.

We re-conceive an activity system or structure in the context of identity formation within communities of practices (please note the bold marking in the figure). Instead of 'subject' we adopt the entire members of the community as 'subjects in the community'. These subjects are always in constant (implicit and explicit) recognition of their 'identity', for example, as academics in the University setting.

Towards a Design Framework for CoP

We recommend a design framework that focuses on four levels. At the Identity level, when a new community is formed, identity be identified and subjects with common interests, but with complementary backgrounds recruited first. However, this does not mean that the identity is static for new comers to appropriate. Rather, it should be seen as a starting point for an ongoing evolving process. Subsequent developments and interactions within the community with the gained experience and implicit institutional knowledge over time will shape the community identity and regulatory rules. Enabling tools are subsequently designed for general purpose interactions.

At the community level, ground rules are set before the commencement of any activities. These ground rules regulate how members interact with one another, how various activities contribute to the attainment of the community vision and how a specific community interacts with other related communities. Again, tools are designed to enable these interactions.

At the activity level, when we design community-based activities, objects for specific activities must be spelled out clearly. It must have a clearly defined associate outcome. In addition, it must meet the criteria of situatedness, commonality and interdependency. Only after that, activity-related rules can be articulated and roles assigned. The employment of supporting tools only come after all the above are appropriately delineated and aligned.

At the personal level, there are personal "agendas" for individuals participating in an activity. Participants also need to set their own "rules" for this particular activity and how this interacts with other activities that they are involved at the same time. They also need to integrate all different roles they play in different activities

Note that there are no roles at the community level, because roles only make sense when people are engaged in community-based activities. For example, when we refer to the CEO of a company, we immediately associate that role with a number of activities that this person has to be involved. Without those associated activities, one cannot even be seen as a CEO. These roles exist regardless whether the associated activity is underway or not. But, these roles are functional only when these people are engaged in activities that require the presence of this role.

A case example of designing a degree program based on the CoP approach

We now apply the framework to designing university degree programs. The design at the community level can be likened to the design of a degree program, whereas the design at the activity level are largely within individual courses. Our recent experience in setting up a Postgraduate Diploma in Applied e-Learning is a good example to illustrate how this framework.

One realization we have is that one course cannot form a community and that's why most attempts to adopt CoP/CoL into the course failed. Fundamentally, for a community to survive and sustain, the members cannot be fixed and there should not be time limits. Otherwise, once the key people lost interests/momentum, the group dies in no time. A course cannot be a community because there are fixed people and the lifetime is finite. Once the assessment is due. That's it. Not more interactions.

So, the community should be at the program level (at least) or higher (e.g. the whole university). If we ever want to adopt this CoP philosophy in schools or universities, we need to run a program like a community. Students can come and go, but the program (community identity) stays. Each individual courses within the program, then becomes activities.

One feature of such a program is that students are constantly involved in the community. This participation is part of the core (compulsory) course that they have to take. As part of the core, they have to work with a senior on the senior's internship projects. As they become senior, they work with new comers on the internship of their choice. This is to model the process of legitimate peripheral participation.

Students are also required to develop their pathway through the program as part of this core course. This core is then extended to the internship course. There should not be clear distinction between the two. Each student will be assigned a supervisor to guide him/her. There will be plenty of opportunities for them to learn from each other and work with practitioners (through the various projects). The optional "courses" are different projects/activities that they will be involved. All learning is situated/project-based/problem-based/community-based!

Assessments will be done via portfolios. A competency checklist will be introduced as a tool for determining quality of their learning. Students will have to make a public presentation about their portfolio as part of the assessment. A panel of lecturers will be involved to assess. Table 1 shows design activities and outcome of the design at each level when applying the design to a university degree program.

Level	Design activity (Infrastructure)	Outcomes
Identity	Community identity identified	Philosophy, Visions, Beliefs documented
	Subjects recruited	Student profile, graduate profile,l ecturer profile Internship partners profile
Community	Ground rules set	Pathway analysis, course structure, graduate competency check list, code of conduct, interaction with other communities
	Tools designed and employed	Tools support the above
Activity	Object of activity specified	Course competency checklist, project outcomes
	Rules for interaction set	Collaboration w/ other team members Collaboration w/ other courses (activities) Assessment clarified
	Roles assigned	Roles of team members assigned Roles of this course and others assigned
	Tools designed and employed	Previous cases bank, tools support the above
Personal	Rules negotiated	Personal commitments Personal time/resource management
	Roles integrated	Integrating assigned roles into an integrated whole
	Tools designed and employed	Personal prior learning experience Tools designed to support the above

Concluding Remarks

In this paper we have proposed an exciting framework for designing community-based collaborative learning activities. It focuses on setting the structure right to start with and thus increase the possibility for a successful development. In a way, this is a organic approach to learning. Unlike the traditional design approach which takes a mechanistic view to learning and treats learning a predictable journey, our proposed approach to learning is like gardening. We may design how the garden may look like, but much is uncertain and much is attributed to the process of planting and pruning. With other scaffolding and augmenting approaches to learning, this framework offer a more promising result than other traditional approaches to education design.

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Using Social Network Analysis to Explore the Dynamics of Tele-mentors' Meta-support in Practice

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Abstract. Little research has been conducted on human support in CSCL situations. Extensive investigations on human meta-support are, in fact, rare. In this study, we have developed a set of mechanisms to facilitate human meta-support in a CSCL environment. Thirteen cognitive-affective pairs of mentors who facilitate a total of 82 forum groups share and discuss their mentoring practice in an exclusive Mentoring Forum. Using Social Network Analysis, we have explored the dynamics within and among pairs of mentors to reveal how they engaged in this environment and how they co-constructed their knowledge on how best to support a group of learners.
Keywords: meta-support, paired telementors, synergetic scaffolding, SNA

Introduction

Much software has been designed to support the learning of individual mentees while little to none has been developed to support telementors in sharing their ideas and beliefs on synergetic mentoring. Our research team has developed a web-based software suite designed to support telementoring in our inquiry-based science learning programs, Lain (Learning Atmospheric science via InterNet). In this study, we focus upon analyzing the interaction of telementors in an exclusive, Mentoring Forum. Within this private area, telementors can share and seek advice from colleagues before taking action. Our goal was to explore the dynamics among telementors and to examine how such a simple mechanism can facilitate the practice of meta-support and also enhance synergetic telementoring. We first explore how these telementors utilize a private forum as a resource for human meta-support, then identify how these pairs of telementors interact with each other and other pairs in a mentoring community.

Methods

Twenty-six volunteer mentors (13 males and 13 females) participated in facilitating 491 high school learners in a virtual summer camp in Lain 2003. Mentors were paired according to their academic backgrounds, those majoring in the sciences as cognitive mentor (mentor A) and those with non-science majors as affective mentor (mentor B). In participation-oriented practice, cognitive mentors are responsible both for fostering mentee learning of content and also learning how to participate in collaborative inquiry discourse practices. Affective mentors, on the other hand, engage in an intensive effort to get mentees to do inquiry themselves, for example, to pose questions themselves, as well as to pursue their own explanations in scientific practice. Since the camp was held during summer, most of the volunteers were elementary to secondary school teachers or graduate students with majors in the learning sciences. Together, they posted a total of 2936 articles over six weeks. On average, each mentor posted 112 articles in 5-8 group forums.

We designed two levels of meta-support mechanisms for them. One mechanism exists at the within-paired level, Footnotes. The other mechanism exists at the between-paired level Mentoring Forum a general forum for all telementors. The Mentoring Forum is designed to enable them to have a "coffee break" in the teacher's lounge whenever they choose to share their mentoring experiences from different forums. Since mentees are prohibited from entering this space, telementors can also share their impressions and personal concerns about things that have happened in their respective group forums.

Postings from the Mentoring Forum may be treated as relational data, stored in a matrix, and subjected to an analysis of interaction patterns. Social Network Analysis (SNA) is used to analyze the social structure of such a mentoring COP. Our approach differed from that of many researchers who have used email communication in a distributed community of learners (Sylvan, 2006), or have used the number of messages written and how many times and by whom a certain message was read (de Laat, 2004; Reffay & Chanier, 2003); but was conceptually similar to indirect relationship networks, which used relationships established through a shared object (such as the creation and later reading of a document in a shared workspace)(Martinez, et.al., 2006) as entry data for SNA.

However, we developed an alternative way to transform the interaction dynamics of the mentors within such a forum. To illustrate: We regard the contributors to any single thread as having similar interests in response to that issue. The social network relationship is defined for each couple (a,b) in a thread, in terms of *joint contribution* to that same thread. In other words, we count the relationship of co-construction by measuring the proximities between two agents instead of just agent a opening a message which is posted by the agent b. Therefore the conceptual unit of analysis becomes the thread, rather than the posting. Following this approach, we first created a thread-by-participant table, and then transformed it into a participant by participant matrix. This network proximity (Cho, Stefanone, & Gay, 2002) matrix was then used as input data to generate an SNA graph to identify how these pairs of telementors interacted with each other and to what extent the same/different roles of telementors (e.g., cognitive mentor A or affective mentor B) had common interests in contributing to various mentoring issues. For the purpose of exploring telementors' social network relationships, we excluded the postings of the coordinators from the following analysis.

The Mentoring Forum Activity

Table 2 shows the distribution of 13 pairs of telementors among the remaining 630 postings. On average, the mentors contributed 24 postings each. The standard deviation was 20. 32 percent of threads consisted of a single posting, which brought the average length of threads down to 3 postings each. As we can see in table 2, mentor B contributed more postings in general than did mentor A. There were three mentors B (7B, 9B, 12B) and one mentor A (7A) who were very active and shared more than 50 articles in this forum. From this paired distribution, we notice that paired mentors of both #4, #10 and #13 contributed very few postings. Mentors 3B and 9B have significantly higher posting counts than did their assigned pairs 3A and 9A. In order to explore how these interactions intertwined among pairs in juxtaposition with the different roles of the telementors, we need further examination with SNA to uncover the communication structure of the mentors as a group.

The Dynamics of Telementors

In order to measure the proximities among these mentors in terms of their contributions to the same threads, the co-occurrence of postings between every two mentors were counted (Table 2). From this matrix, we identified a couple of mentors who had similar interests when engaging in the Mentoring Forum. Information in Table 2 can be explored in terms of the affective role shown in the bottom-right, the cognitive role in the upper-left area, and A-B paired mentors in the bottom-left area along with the diagonal line, and finally in terms of A-B outside their assigned pairs shown in the bottom-left area, respectively. This matrix also shows that the interaction among affective mentors seems to take place with greater frequency than that of cognitive mentors.

Table 1 The distribution of postings among 26 telementors

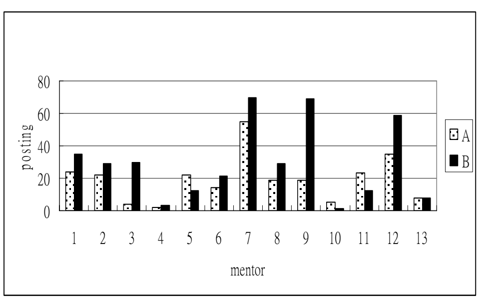

Table 2 The matrix of co-occurrence of cognitive-affective paired mentors contributing to the same thread

	01A	02A	03A	04A	05A	06A	07A	08A	09A	10A	11A	12A	13A	01B	02B	03B	04B	05B	06B	07B	08B	09B	10B	11B	12B	13B
01A	0	-	-	-	-	-	-	-	-	-	-	-	-	6	5	2	0	0	2	2	3	3	0	1	3	1
02A	4	0	-	-	-	-	-	-	-	-	-	-	-	1	3	1	0	0	1	3	3	2	0	1	3	1
03A	2	2	0	-	-	-	-	-	-	-	-	-	-	1	2	0	0	0	1	1	1	1	0	0	2	1
04A	0	1	0	0	-	-	-	-	-	-	-	-	-	0	0	2	0	0	0	0	1	0	0	0	1	0
05A	2	2	1	0	0	-	-	-	-	-	-	-	-	2	2	0	0	3	3	3	1	2	0	1	1	1
06A	2	3	0	1	3	0	-	-	-	-	-	-	-	1	2	2	0	0	1	3	2	1	0	1	1	0
07A	3	2	1	0	3	1	0	-	-	-	-	-	-	2	2	1	0	0	2	17	1	8	0	2	6	3
08A	2	3	0	1	3	4	1	0	-	-	-	-	-	1	2	3	0	3	2	5	2	5	0	1	1	0
09A	2	2	1	1	2	1	3	3	0	-	-	-	-	2	3	1	1	3	2	6	0	9	0	0	3	1
10A	1	3	1	0	2	2	1	2	0	0	-	-	-	1	2	0	0	0	2	1	2	0	0	1	1	0
11A	1	2	0	1	5	3	2	5	3	2	0	-	-	1	2	2	0	2	3	4	4	2	0	3	3	0
12A	0	0	0	0	0	1	0	1	0	0	0	0	-	1	1	0	0	1	0	1	1	1	0	0	11	0
13A	2	2	0	0	4	3	1	4	2	2	4	0	0	1	2	0	0	1	3	3	2	2	0	1	0	0
01B	6	1	1	0	2	1	2	1	2	1	1	1	1	0	-	-	-	-	-	-	-	-	-	-	-	-
02B	5	3	2	0	2	2	2	2	3	2	2	1	2	8	0	-	-	-	-	-	-	-	-	-	-	-
03B	2	1	0	2	0	2	1	3	1	0	2	0	0	3	1	0	-	-	-	-	-	-	-	-	-	-
04B	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	-	-	-	-	-	-	-	-	-
05B	0	0	0	0	3	0	0	3	3	0	2	1	1	1	1	0	1	0	-	-	-	-	-	-	-	-
06B	2	1	1	0	3	1	2	2	2	2	3	0	3	1	3	1	0	1	0	-	-	-	-	-	-	-
07B	2	3	1	0	3	3	17	5	6	1	4	1	3	2	4	2	0	3	8	0	-	-	-	-	-	-
08B	3	3	1	1	1	2	1	2	0	2	4	1	2	3	5	4	0	2	4	4	0	-	-	-	-	-
09B	3	2	1	0	2	1	8	5	9	0	2	1	2	3	4	2	1	4	5	14	4	0	-	-	-	-
10B	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	-	-
11B	1	1	0	0	1	1	2	1	0	1	3	0	1	1	0	0	0	0	0	2	0	0	0	0	-	-
12B	3	3	2	1	1	1	6	1	3	1	3	11	0	6	4	3	0	0	5	6	7	5	0	1	0	-
13B	1	1	1	0	1	0	3	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	1	0

This initial proximities analysis in Table 2 was very helpful in interpreting the results of SNA in Figures 1 and 2. In Figure 1, the graph shows the entire social network of 26 mentors. Lines between members indicate that they jointly contributed to the same thread. The relationships between the different nodes indicate roughly which mentors were more closely linked to others. From this graph we see two subgroups in terms of the roles: one cluster at the lower part of the graph is composed mainly of cognitive mentors, with the exception of two affective mentors, 5B and 11B; and the other at the upper part is composed mostly of affective mentors, with the two cognitive mentors, 12A and 1A, appearing about the periphery and one at the center (7A) surrounded by all the affective mentors. It's very interesting to explore further what happened in this social network.

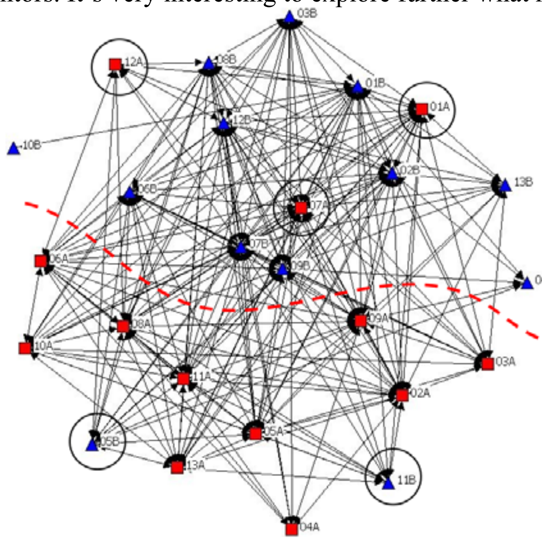

Fig.1 Graphical representation of forum contribution

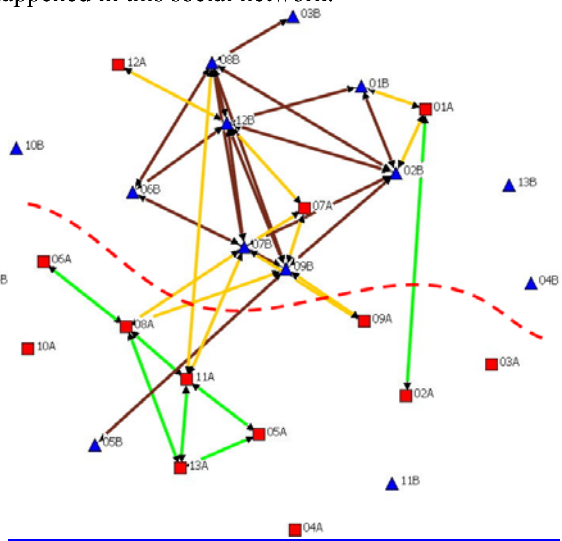

Fig. 2 Reduced graphical representation of forum contribution

The graph in Figure 2 is identical to Figure 1 but shows only co-occurrence instances greater than 3. By comparing all interactions in Figure 1 with the strong co-occurrence in Figure 2, we can see better where stronger interactions exist. The smaller group consists mainly of five cognitive mentors, while the other bigger one consists of eight affective mentors and three cognitive mentors. The insights provided by this reduced graph imply several things. Firstly, the more active cognitive mentors in the bigger subgroup either shared cognitive domain knowledge that was needed by these non-science major affective mentors, or they were jointly engaging in affective affairs. It is these four cognitive mentors, 7A, 12A, and 1A who developed more connections with affective mentors and promoted distributed expertise within these telementoring communities. Secondly, although some of the paired mentors frequently share cases occurring in their respective group forums with all the other colleagues (e.g., 12A and 12B), the active cognitive mentors also pursued discussions on many similar subjects of interest with other affective mentors as well. Thirdly, the members that bridge two subgroups of social networks are 7B, 9B, and 8B for the affective mentors and 8A and 11A for the cognitive mentors. The SNA shows that their interests cross the boundary between the same role and the assigned pairs.

We made some cautious modification to analyzing social networks with SNA. We put emphasis on the proximities of persons contributing to the same thread, rather than on a loose correlation of the relationship of message reading and sending. The results show that, besides the pre-assigned pairing of these mentors, the SNA graphs also reveal links among cognitive as well as affective mentors of different pairs. Two clusters with mixed types of interaction represented in our reduced social network graphing provide evidence of synergetic scaffolding in the Mentoring Forum. From this point of view, telementors participate in their own forums, and observe colleagues in their respective forums, and, mediated simultaneously thus by the Mentoring Forum, are supported in becoming more reflective about, and conscious of what they are doing, and thereby develop more meta-knowledge on how best to implement scaffolding in their community.

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Effects of Previous Messages' Evaluations, Knowledge Content, Social Cues and Personal Information on the Current Message During Online Discussion

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Abstract: This study of the flow of online discussions examined how previous messages affected the current message along five dimensions: (1) evaluations (agreement, disagreement, or unresponsive actions); (2) knowledge content (contribution, repetition, or null content); (3) social cues (positive, negative, or none); (4) personal information (number of visits); and (5) elicitation (eliciting response or not). Using dynamic multilevel analysis (DMA) and a structural equation model (SEM), this study analyzed 131 messages of 47 participants across seven topics in the mathematics forum of a university Bulletin Board System (BBS) Website. Results showed that a disagreement or contribution in the previous message yielded more disagreements and social cue displays in the current message. Unlike face-to-face discussions, online discussion messages that disagreed with a previous message elicited more responses. Together, these results suggest that teachers can use and manage online discussions to promote critical thinking, facilitate discussion of controversial topics, and reduce status effects.

Studies on FTF discussions have shown that the actions of earlier speakers can affect those of the current speaker. For example, a person is more likely to agree if the previous speaker agreed (Chiu & Khoo, 2003). Hence, earlier messages might also affect later messages in online forums. By understanding how online discussions evolve message by message, educators can improve their quality and facilitate student learning.

Most previous studies on online discussions examined the *individual* properties of each message (Tallent-Runnels et al., 2006; De Wever, Schellens, Valcke, & Van Keer, 2005; Hara, Bonk, & Angeli, 2000; Schellens & Valcke, 2005). Their results showed that many students processed course information at high cognitive levels during online discussions, supporting the claim that online discussion can promote active and critical thinking (Garrison, Anderson, & Archer, 2000, 2001).

Using data on 131 messages by 47 respondents on seven topics, we extend this line of research in three ways. First, we propose a framework for examining the *relationships* among messages in an online independent academic forum. Our framework consists of an online message's evaluation of the previous message (agreement, disagreement, or unresponsive actions), its knowledge content (contribution, repetition, or null content), its social cues (positive, negative, or none), displayed personal information (number of visits, nickname, and personal statement), and its elicitation of other messages (eliciting response or not). Second, we explicate a new methodology for analyzing these relationships, a modified version of Chiu and Khoo's (2005) dynamic multilevel analyses. Lastly, we apply this revised method to test how earlier messages' evaluations, knowledge content, social cues, and personal information affected the properties of each message in a mathematics forum on a Bulletin Board System (BBS) Website.

Data and Analyses

In this data set, 47 participants posted 131 reply messages across seven topics. These topics were among the most popular discussions on the mathematics board of Peking University BBS Website (URL: bbs.pku.edu.cn) from May to October, 2004. Peking University students are among the best students of China and are usually 18 to 30 years old (from undergraduate to postgraduate). Gender information was unknown.

The set of variables (see table 1) for a single message included number of visits by each e-poster and the following binary variables: agreement, disagreement, contribution, repetition, social cue, negative social cue, and elicitation. Values of zero for Agreement and Disagreement indicate an unresponsive action. Likewise, values of zero for Contribution and Repetition indicate Null content. Also, values of one for Social cue and zero for Negative social cue indicate Positive social cue.

Table 1: Message properties to be examined in the study.

Message properties	Example
Agreement	"I agree with you."; "Good answer. Can you say more?"
Disagreement	"I *don't* think so."; "That's partially right, *but*, …"
Unresponsive / new topic	"This reminds of an interesting story …"
Contribution	"*In my opinion*, …"; "we can *multiply rate times time*"
Repetition	"Yes, you're right. Two times six is twelve, not ten."
Null content	"Yes"; "Thank you"; "I don't understand"
Positive social cue	"Excellent!"
Negative social cue	"That's ridiculous!"
Non-personal social cue	"Two times three equals six"
Visits	E-poster's visits on the BBS website, e.g., *791*.

This analysis uses three sets of variables: properties of the current message (0), properties of earlier messages variables in the same thread (-n, where n = 1, 2, 3, …), and properties of the next message (+1) in the same thread. For example, contribution (0) indicates whether the current message includes a new idea. Likewise, repetition (-1) indicates whether the previous message in the thread repeated an earlier message. Lastly, elicitation (+1) indicates whether or not a message responded to the current message.

To statistically analyze interactions among online messages, we must address three major concerns. First, e-posters' behaviors and effects differ across topics, yielding nested data. Second, most variables in this study are discrete, not continuous. Third, messages are often similar to recent events in time-series data, so the values of variables tend to depend on the values of these variables from recent messages.

Ordinary least squares (OLS) regressions do not address these difficulties (Goldstein, 1995; Enders, 1995). We address these difficulties using an extension of *dynamic multilevel analysis* (Chiu & Khoo, 2003, 2005). We test for topic differences, build an explanatory model, test for serial correlation, and model direct and indirect effects. Extending Chiu and Khoo (2005), we also use a structural equation model to test all predictor effects simultaneously.

Results and Discussion

The multi-level variance components analysis showed that topics did not differ significantly (variance at the topic level was not significant), so single-level analyses were adequate. Based on dynamic multilevel analysis results, we used an SEM to test the direct and indirect effects of the earlier messages. Non-significant effects in the SEM were removed. The final model is shown in figure 1.

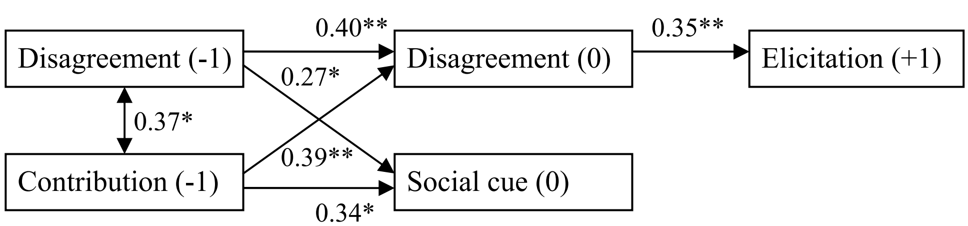

Figure 1. Structural equation model for predictors of disagreement, social cue and elicitation with significant standardized parameter estimates (χ^2 [df = 5, N = 109] = 8.19, p = .146).

As expected, disagreements often occurred after prior disagreements and contributions in this study. A message that disagrees with an earlier message yielded further disagreements, consistent with Chiu and Khoo's (2003) FTF interaction result. Unlike FTF interactions however, disagreements did not seem to threaten the continuation of the discussion, as disagreements raised the likelihood of later e-posters' responses. These effects suggest that online discussions are suited to controversial topics.

Both disagreement and contribution in the previous message positively predicted a social cue in the current message. This result suggests that in online discussions, disagreements and new ideas tend to cause stronger emotional responses and engagement compared to other types of messages. Also, disagreements and contributions elicited more responses, suggesting that messages are more provocative and engaged students to respond. Furthermore, these results showed that messages with critical thinking were more popular, which supports the claim that online discussion forum can promote critical thinking (Garrison et al., 2000, 2001).

There were also several notable non-significant results. Contrary to Walther's (1996) and Henri's (1992) arguments, social cues did not substantially affect the behaviors studied. Furthermore, status in the form of number of visits was linked to more contributions, suggesting that experienced e-posters elicited more contributions. However, agreements did not occur more often after messages by e-posters with more visits. Likewise disagreements were not less likely after messages by e-posters with more visits. Together, these results support our hypothesis that status effects are weaker in online discussions than in FTF discussions.

Implications

This study showed that disagreements and contributions affected the likelihoods of later disagreements, social cues and responses. If future studies support the results of this study, then educators and researchers might use online academic discussion in three ways: (1) *Developing controversial discussions on online forums*. As shown in this study, participants were likely to engage in and sustain online discussion on topics that involved many disagreements. This result suggests that educators might help students learn and think critically by using online forums for discussion of controversial topics, e.g., new hypotheses or problems with contested answers. (2) *Reducing status effects*. This study showed that experience status effects are much weaker in online discussions than in FTF discussions. If status effects are a serious problem in classroom interactions, online discussions among multiple classes (or schools) or perhaps with pseudonyms might mitigate these status effects. (3) *Managing online discussions at message level*. This study suggested that the property of previous messages may affect the current messages in a discussion thread. It implies that, in addition to encouraging student to participate, teachers may also manage the online academic discussions for specific purposes at message level.

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Understanding Pair-Programming from a Socio-cultural Perspective

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Abstract: Pair-programming has been used more and more often in educational settings. Although some studies have been conducted and pair-programming was found in these studies more effective for students to learn programming, very few studies have focused on the interactions between the paired students during the pair-programming process. The study reported in this paper seeks to understand the learner's activities by taking a closer look at the interactions between the pair from a socio-cultural perspective.

Introduction

Pair-programming is one of the 12 practices in XP (Beck, 2000) where two persons sit in pairs working on a problem apposed to a more isolated single-programmer situation. One person, the driver, is in control of the keyboard or pencil, while the other, the observer, actively observes the driver. The observer uses resources to find better solutions, watch for defects in the code and together they collaborate and discuss problems they encounter and in that way knowledge constantly is shared between them. They can periodically switch positions and both work towards a shared goal. Beck (2000) emphasizes that pair-programming is not an activity where one is doing the work and the other is just watching. Pair-programming is a dialog between two persons trying to program together at the same time and together understand how to program better.

Research shows that using pair-programming in an educational setting is effective for teaching students how to program (Preston, 2006; McDowell et al., 2003; Williams & Upchurch, 2001) and it results in higher quality programs, greater understanding of programming process, decreased dependencies on teachers, improved course completion rates and scores, and decreased time to complete programs. However, most of the research take a quantitative method and focus on a rather big number of students in a programming course. Very few researches have studied intensively the interactions between members of the pair during the pair-programming process. The study reported in this paper seeks to understand the learner's activities by taking a close look at the interactions between the pair from a socio-cultural perspective.

Experiment

The experiment was conducted over a period of four days. Eight students in a first year introductory course in object-oriented programming participated in the experiment – seven males and one female. The students were beginners regarding programming and object-orientation although their skills and experiences differed. They were paired up forming four groups and scheduled to meet at the research location one group each day. Each session lasted approximately four hours including one break.

The experiment was conducted in a room with a table and two chairs. One laptop was set up with an external keyboard and a mouse. The main focus in this experiment is to capture the collaboration between the participants and how they interact with each other. The camera was therefore positioned in front of them. From this angle the screen was not captured. This was resolved by streaming pictures of the screen onto the laptop. Both video and screen pictures were streamed on to a hard drive. A large extent of the activity in the room was framed by these two views. The teachers/researchers were situated in the next room observing all the activity on monitors and they could at any time enter the room of the experiment. They could initiate contact when the participants had problems with the software or when they were stuck on a task. Participants could also initiate the contact by asking for help. The camera recorded all activities between teachers/researchers and participants. The participants were presented a written assignment text including a set of four tasks. They also received 600 lines of Java code with initial functions as a starting point, both printed version and electronic version, and a graphical sketch of the data structures in the program they were to work on.

Data Analysis and Findings

In this study the research focus is on collaboration between students in a learning situation. A number of guiding questions were identified and interesting segments from the video were analysis accordingly. In this paper we focus on one guiding question: *How do the pair-programming rules (especially the driver/observer rules) affect the interaction between paired students?* According to Vygotsky (1978) a learner should have constraints (e.g. rules) to help them interact with his or her surrounding elements, but constraints and freedom must be balanced to create a constructive situation for the person. In pair-programming member's activities are strongly influenced by the role she/he takes.

In the following segment the participants in Group 3 are working on Task 2 and the method finnLedigFirma. They have discussed the assignment and possible solutions, but they are uncertain and decide to consult the assignment text before they continue working on the problem. In the following segment the observer suggests using the variable 'kapasitet' in order to find the firm with free capacity (line 186 and 188), but the driver doesn't follow up on the proposed idea. The driver continues with his own ideas and the observer follows his suggestions and agrees with them. They continue talking in turns and the driver types what they agree on.

Line	Time	Activity	Actor	Conversation
184	00:30:00	Reaches for the assignment text	Driver	Let's see the assignment text
185	00:30:13	Reads from the text	Driver	Find and select the first Byggefirma with free capacity
186	00:30:25	Looks at the printed code	Observer	Then we have to check the 'kapasitet' thing also
187	00:30:27	Confirming	Driver	Yes
188	00:30:30		Observer	We can check the capacity… And then…
189	00:30:38	Interrupts the observer	Driver	We must have the variable 'funnet' and then we can have a while-loop which checks on the Byggefirma… the firmaliste…
190	00:30:55	Looking at a code segment in the printed code	Observer	If we use this one… Hmmm… Then we can just set a boolean…
191	00:31:05		Driver	Yes
192	00:31:10		Observer	We must have one that limits the method so we don't put in where there is no capacity. Right?

From line 221 the observer again tries to suggest using the variable 'kapasitet' (see line 186). But the driver still ignores it and now he is no longer responding to the observer. The communication breaks down and the driver types without consulting his peer. The observer then becomes frustrated and he takes control over the keyboard and types in his suggestion (line 225). This action forces the driver to think carefully about what the observer has suggested. From the later actions, we can see that the driver ends up with actually following the observer's suggestion. They continue collaborating and end up with a solution that is very similar to what was written in line 225.

Line	Time	Activity	Actor	Conversation
221	00:39:30		Observer	But it must be with byggefirma dot… Or… It's a different class… Or has it an array?
222	00:39:50	Without answering he types in more in the method	Driver	Funnet = true; And we need an else if.
223	00:40:16		Observer	Yes, that's if it is zero? Or?
224	00:40:17	Doesn't answer	Driver	
225	00:40:22	Takes the keyboard and types his suggestion	Observer	I have to write this…
226	00:40:50	Looking at the screen before he takes control over the keyboard again and deletes what the observer wrote	Driver	Oh! You then must search in the firm's antall
227	00:41:20	Studying Byggefirma class	Driver	Firmaliste.søknader, then
228	00:41:36		Observer	Yes, antall. What I mean is that if antall is

				equal or larger than 1 and less than capacity… You see?
229	00:42:27		Driver	Wait a minute…
230	00:42:58		Observer	Yes, we have to look at when they have one or more applications in…. Can we use many AND in a statement?
231	00:43:10	Types in code similar to what the observer did in line 225	Driver	
232	00:43:10	Saves file and compiles. It seems to work.	Driver	Yes, I think so. Let's see if what we have is ok.

The driver/observer rule, where the driver has control over the keyboard while the observer is commenting and participating in the discussion of what should be written, is made explicit through the psychical restrictions that the two students only had one keyboard and it enforces an equal division of labor in the group. According to Kuutti (1996), when members of a community follow the same rules they are able to work towards a common objective and the embedded rules support the communication on an operational. When participants fail to follow the same rules a contradiction appears and harms the communication between them. In order to restore communications the conflict must be resolved by visualizing the rules and make all members aware of them. The rules are then supporting the communication on an action level. In the above segment a contradiction appears. The observer suggests a solution (line 186) but the driver ignores him. After a while the observer expresses the same solution only to get no reaction from the driver. The rules are broken since the driver does not listen to the observer (line 221 – 224) and the activities towards their objective (finishing the assignment) is harmed by it. To restore the communication the observer "oversteps" the guiding driver/observer rule and takes the keyboard (line 225). With this action he makes the driver shift his focus from his own individual work to the social collaboration between the two students and he makes visible that they are both equally connected to the task they are working on. When the rules are visible they support the communication on an action level and this restores the relation between them. As an outcome of this contradiction the students came closer to completing the task since the observer's opinion was.

The activities in the above segment show that it is necessary for the students to follow the pair-programming rules and that it helps the communication between them. When they are aware of each other and have equal influence in the decision-making process, they are able to work together towards finishing the assignment. If one of them does not include the other in their problem-solving he or she needs to be reminded. In the segment above we see such a contradiction occurs and the participants are able to solve it by themselves.

Conclusion

The goal of this research is to understand learners' activities in pair-programming process. We analyze the activities from four pair-programming processes. The focus of this paper is the effect of driver/observer rule on the interactions. The analysis indicates that in pair-programming, the driver/observer rule facilitates collaboration by providing pairs with opportunities to think aloud and reflect. However, this does not mean that pair-programming is automatically a success. Constructive pair-programming depends on the peers' engagement (to the process) and how well they comply with the guiding principles.

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Learning Writing By Reviewing In Science

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Abstract. We examined a theoretical perspective on reciprocal peer reviewing of writing. As an alternative to the traditional approach, *Learning Writing by Writing*, focusing on increasing writing opportunities, we proposed and tested a new hypothesis, *Learning Writing by Reviewing.* Reviewing is defined as a problem solving activity of practicing problem detection, diagnosis, and solution generation in peer writing. The results supported the hypothesis in that peer reviewers improve their own writing by reviewing peer writing.

In spite of extensive efforts for the past three decades under the Writing-Across-Curriculum (WAC) and the Writing-in-the-Disciplines (WID) movements, being able to write well is a fundamental skill that most students in the U.S. lack across all ages. The National Assessment of Educational Progress in 2002 found that 69% of 8^{th} grade students and 77% of 12^{th} grade students were found to have only basic or lower levels of writing skills (Persky, Daane, & Jin, 2003). Other age group students also performed poorly. Not surprisingly, a great number of high school graduates in the U.S. remain at a lower level of writing skill (Kamil, 2003) than is expected by colleges and employers. Accordingly, the U.S. National Commission on Writing (2003) argues that improving writing across the board should be a national goal of the U.S. They argue that a fundamental reason for this unfortunate situation is that students do not have opportunity of writing practices because instructors are simply overwhelmed by the workload related to reading, grading, and commenting on student writing assignments. Therefore they tend to avoid instructing writing assignments in their courses (National Commission on Writing, 2003).

On the basis of findings that writing improves across multiple drafts as a function of feedback (Hayes, Flower, Schriver, Stratman, & Carey, 1987), a natural, dominant response is to endow students with more chances of practicing writing with feedback. We term this general approach as *Learning Writing by Writing*. This approach tries to make feedback available for students to help guide the writing practice. For example, as part of the WAC and WID movements, considerable resources have been devoted to having a few writing-intensive experiences where instructors or TAs give students opportunities of writing practice with feedback. Another variation of the approach is to outsource feedback beyond instructors. An interesting example is that at Texas Tech, freshmen submit their writing to a system, and then this writing is graded by a graduate student from a pool of such graders (Wasley, 2006).

By contrast to the traditional approach that is dominant, we propose a different perspective, called *Learning Writing by Reviewing*, analogous to the reciprocal teaching approaches to early reading instruction. This perspective emphasizes that learners may improve their own writing skills by engaging in peer review of writing (e.g., Rushton, Ramsey, & Rada, 1993). We define reviewing as a process of problem solving in which reviewers are engaged in exercising important skills for writing (Bereiter & Scardamalia, 1987; Fitzgerald, 1987; Flower, Hayes, Carey, Schriver, & Stratman, 1986) such as problem detection, diagnosis, and solution generation along with reading and commenting on peer writing. These activities may improve reviewers' own writing and revising skills by reinforcing successful strategies and by calling attention to unsuccessful strategies that the reviewers have already used in their own writing. Thus, the goal of this study is to extend the value of peer reviewing beyond its practical advantage by examining how doing peer reviews helps reviewer's own writing skill development.

It is important to note that there are currently barriers restricting practical use and adoption of peer reviewing. Due to the demanding nature of reading and commenting on papers, students as well as instructors are leery of using peer commenting. From the instructors, peer reviewing activities can be perceived at having an opportunity cost—what other instructional activities could students be engaged in? From the students' point of view, commenting is the job of the instructor, not the students. A fundamental reason is that students are not only novices in their disciplines, but also are inexperienced in writing and reviewing. If the reviewing activity had its own pedagogical merit, these concerns might be allayed.

Method

Initially 145 college students in three intro Physics courses participated in this study as a part of their course requirements. Each student was asked to write first draft and revised draft of two technical research papers. In addition, each student reviewer was randomly assigned four peer papers. Thus, each student submitted first drafts, reviewed four peer drafts, received comments on their writing from peer reviewers, and then revised their first drafts. The reviews were double-blind: authors had pseudonyms and reviewers merely were numbers to the authors. It was important to controlling for floor and ceiling effect on the writing quality evaluation scale because very low writing scores often reflect complete lack of effort on the writer's part, and very strong first drafts have little incentive to revise the paper further. Therefore, participants whose first writing scores placed in the middle 60 % (n=87) were selected for further data analyses. Individual students played two roles, one of writer and one of reviewer. These selected students were then categorized into a HIGH helpful review group (*n* = 44) and a LOW helpful review group (n = 43) based on reviewing quality, defined in the next section. Although the participants wrote two drafts of two papers, we only used the two drafts of the first paper.

Reviewing quality was defined using helpfulness ratings provided by writers on the peer comments they received. After submitting their final/revised drafts, the writers who received peer reviews evaluated the quality of the reviews on a 7-point rating scale from *Not helpful at all* (1) to *Very helpful* (7) with space provided for optional short responses.

Results

Before analyzing the main hypothesis, we examined the first draft writing scores and the 1st draft reviewing helpfulness ratings between the High helpful review group and the LOW helpful review group to verify that the groups differed only on review helpfulness and not on initial writing ability. As desired, the first draft writing scores between the HIGH helpful review group (M = 5.48, SD = .38 SEM = .06) and LOW helpful review group (M = 5.52, SD = .37, SEM =.06) were not significantly different, suggesting that both groups entered this study with similar writing skills. As manipulated, the review qualities between the HIGH helpful review group (M = 6.20, SD = .28, SEM = .04) and the LOW helpful review group (M = 5.29, SD = .30, SEM = .05) were significantly different, F (1, 85) = 211.13, MSe = 0.09, p < .001.

The number of words used in comments was analyzed to estimate how much effort each group made. As shown in Figure 2, the HIGH helpful review group (*M*=151.3, *SD*= 48.8) put significantly longer comments than the LOW helpful group (*M*=94.7, *SD*=43.2). Also the number of words has a significant correlation with the Helpfulness ratings, r (87) = .63, p. < .05 and with the writing quality improvement, r (87) = .24, p < .05.

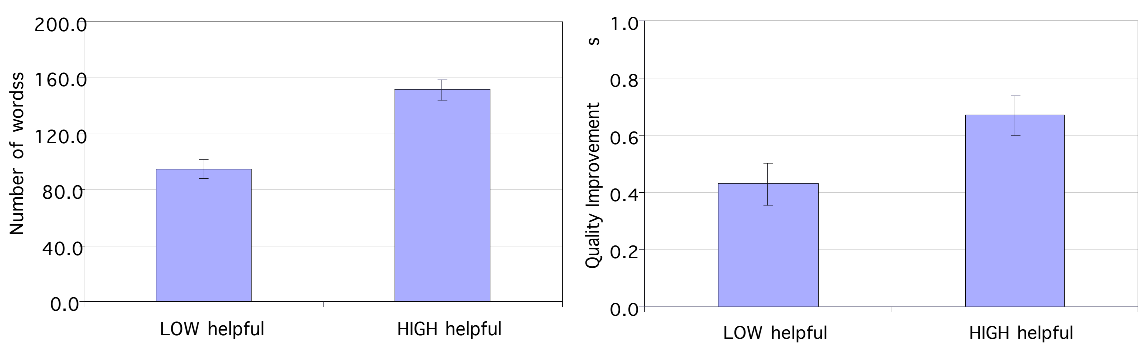

Figure 1. comment length and writing improvement between the LOW and HIGH helpful review groups

To test the *Learning-Writing-By-Reviewing* hypothesis, a one-way analysis of covariance (ANCOVA) was carried out with the first draft writing quality (mean peer evaluation) as a covariate, and the reviewing performance as an independent variable on the final/revised writing quality. The first draft writing quality was used as a covariate because it is very likely to a significant predictor of the quality of revised drafts (Cho & Schunn, 2007), and this approach to assessing predictors of improvement is preferred to using gain scores because gain scores have regression-to-the-mean issues. As shown Figure 1, the final/revised draft writing quality of the HIGH helpful review group (M = 6.15, SD = .46) significantly outperformed the LOW helpful review group (M= 5.95, SD= .48), F (1, 84) = 5.68, MSe = .18, p < .05. The effect size of the improvement of writing quality from the first draft to final draft was medium (*Cohen's d* = .56). In addition, the Pearson correlation analysis revealed that there is a significant relationship between reviewing helpfulness ratings and writing improvement, r (85) = .51, $p < .05$. Thus, these results clearly supported the *Learning-Writing-By-Reviewing* hypothesis.

Discussion

In this paper, we examined the gains for reviewers-as-writers rather than the more traditional empirical focus of reviewers-as-surrogate-feedback for instructor feedback. A moderate effect size was found from the single round of reviewing. Practically, the findings encourage the use and adoption of peer reviewing in addition to its practical advantage of making rich feedback available more often to students. Thus, this research suggests that peer reviewing can empower learning to write from many angles.

One possible alternative explanation involves a third-variable explanation: stronger revisers giving better feedback and also being better able to revise their own papers. However, revision is an element of first draft writing, and the groups were well-matched on first draft scores. If the HIGH helpful group had been better revisers all along, then they would have had higher first draft scores. Note that we did not force the first draft writing scores to be identical—we merely restricted the range to be the middle two-thirds of first draft scores. Therefore, it would have been possible to find first draft score differences.

Although this research supports the proposed Learning-Writing-by-Reviewing hypothesis, several limitations require cautious interpretation of the findings. The reviewing quality measure we used in this study may be limited in that student writers are very likely to prefer praise comments as well as specific comments (Cho, Schunn, & Charney, 2006). While developing praise comments may be useful for authors and may involve practicing some evaluation skills, it seems likely that learning from making specific revision suggestions will have greater transfer to ones own writing than making praise comments. Therefore, it is strongly recommended that further data analysis focus on the content of reviews to examine if comments related to problem detection, diagnosis, and solution are especially associated with gains in one's own writing.

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MUVEs as a powerful means to study situated learning

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Abstract: This paper describes how multi-user virtual environments (MUVEs) can simulate immersive, collaborative learning environments intermediate in complexity between recipe-like lab exercises and real world inquiry situations. We offer the River City MUVE as a case study that illustrates how rich logfiles provide scholars and teachers with detailed data to understand learning processes, to diagnose suboptimal patterns of student performance, and to assess the knowledge and skills students have mastered. This aids curriculum design and theory.

Theoretical Framework

Research on how people learn suggests that learning and cognition are complex social phenomena distributed across mind, activity, space, and time (Chaiklin & Lave, 1993; Hutchins, 1995; Wenger, 1998). A student's engagement and identity as a learner is shaped by his or her collaborative participation in communities and groups, as well as the practices and beliefs of these communities (Wenger, 1998). Yet creating classroom activities that allow students to engage in authentic practices that involve communities of learning is challenging, especially when it comes to authentic practices of science (Chinn and Malhotra, 2002). For example, several investigators (Griffin, 1995; Young, 1993; Hendricks, 2001) developed curricular activities in attempts to validate parts of situated learning theory, but were forced to modify their research designs due to the difficulty of implementing situated learning within the constraints of a K-12 classroom. As an alternative to practices located within a school, bringing students to a local hospital to work with epidemiologists and doctors to study an outbreak of Whooping Cough might provide an authentic, meaningful, and motivating context for students to master scientific content and inquiry skills. Yet, this is not feasible for a myriad of reasons. Until recently, researchers have struggled to conduct research on natural and emergent learning situated in complex and authentic classroom practices in K-12 education.

However, an emerging alternative is to offer students simulated "Alice in Wonderland" experiences via mediated immersion in a multi-user virtual environment (MUVE). MUVEs are online digital contexts where multiple participants can communicate and collaborate on shared challenges. A participant takes on the identity of an *avatar*, one's digital persona in a 3-D virtual world, and communicates via text chat and non-verbal gestures. In a graphical virtual context, participants also interact with digital artifacts, such as viewing pictures or manipulating tools (e.g., an online microscope), and with computer-based agents. MUVEs are unique in their ability to keep minutely detailed records of the moment-by-moment movements, actions, and utterances of each participant in the environment (Ketelhut, Dede, Clarke, Nelson, & Bowman, in press). As such, MUVEs create a context that allows researchers to study emergent learning and cognition across activity, space and time.

MUVEs have been used in education to create online communities for teacher professional development (Bull, Bull, & Kajder, 2004; Schlager, Fusco, & Schank, 2002), to develop science-based activities while promoting socially responsive behavior (Kafai, 2006), to inculcate social and moral development via cultures of enrichment (Barab, Arici, & Jackson, 2005), to foster online communities for students to learn computer programming and collaboration skills (Bruckman, 1997), to engage interest in math (Elliott, 2005), and to develop skills in scientific inquiry (Clarke, Dede, Ketelhut, & Nelson, 2006). This paper presents a brief illustration of how MUVEs offer opportunities to study emergent classroom-based learning experiences intermediate in complexity between recipe-like laboratory activities and complex real world situations.

Situated learning theory is defined as embedded within and inseparable from participating in a system of activity deeply determined by a particular physical and cultural setting (Brown, Collins, Duguid, 1989; Chaiklin & Lave, 1993). The unit of analysis is neither the individual nor the setting, but the relationship between the two, as indicated by the student's level of participation (Greeno, 1998; Barab & Plucker, 2002). From this perspective, learning and cognition are understood both as progress along trajectories of participation in communities of practice and as the ongoing transformation of identity (Greeno, 1998; Wenger, 1998). Through participation in schools, students develop patterns of participation that shape their identities as learners, including the ways in which they engage in learning and hold beliefs about their abilities to learn. As a trajectory, an identity is not an object that one owns once and for all; it is defined over time, evolves, and has a momentum of its own. Identity is what gives a flexible continuity to the various forms of participation in which one is engaged (Eckert & Wenger, 1994, p. 17)

Learning and Research in the River City MUVE

The River City MUVE is a middle school science curriculum designed around national content standards and assessments in biology, ecology, epidemiology, and inquiry. Students work in teams of three to collaboratively solve the problem of why the residents of River City are falling ill. They travel back in time—in the virtual world—to the time period that bacteria were just being discovered. This enables all students to bring their 21st century expertise to a time period in which even the leading scientists were not aware of disease-causing microbes. As students move through the project, they advance through sessions chronologically. Each session represents a different season in River City (Fall 1878 – Fall 1879), allowing them to collect data on change over time.

Unlike a canned lab, the curriculum focuses on the front end of the inquiry process by walking students through the steps of how one first determines a question that can be answered through scientific investigation. Students identify a problem about why people are getting sick and turn it into a question that can be investigated. They then design and carry out an investigation based on one of the three disease strands infecting the city (insect-born, air-born, water-born). Students participate in the curriculum along a trajectory from novice (scientist-in-training) to expert (research scientist), as they learn to develop questions, generate hypotheses, collect and analyze data, and make conclusions and recommendations that they share with others.

According to Greeno (1998), the power of situated learning is derived from a person learning to solve problems as part of a community in authentic context confronting these challenges. Part of the promise of MUVEs is their capability to create immersive, extended experiences with problems and contexts similar to the real world (Clarke, Dede, Ketelhut, & Nelson, 2006). To build collaborative skills, we have designed River City around a realistic problem that is too complex for one student to be able to solve alone within the given time frame. Team members are encouraged to distribute tasks and work together to solve the problem. Logfile analysis gives us a lens through which to study the extent and type of students' collaboration.

As mentioned above, MUVEs are unique in their ability to keep minutely detailed records of the moment-by-moment movements, actions, and utterances of each participant in the environment (Ketelhut, Dede, Clarke, Nelson, & Bowman, in press). These data form the basis of a personal MUVE history of each student that follows him or her from session to session, in the form of extensive log files—a feature impossible to replicate in a classroom-based experience. The level of detail in these records is extensive: the logs indicate exactly where students went, with whom they communicated, what they said in these interactions, what virtual artifacts they activated, and how long each of these activities took. Analysis of these log files allows us to understand patterns of behavior, such as development of community norms, conversational practices, and trajectories of participation.

We closely examined log files of three classes of students in the 7th grade (n=54), all taught by the same science teacher, in an urban public middle school in the Northeast. The level of analysis was the team of students, and we looked at each session as a separate "chunk" in order to understand how students' participation changed over time. In order to assess how students were participating, we developed a set of codes based on aspects of authentic inquiry and situated learning (trajectories of participation, conversational practices, community norms, confronting ineffective strategies and misconceptions, distributed cognition, cognitive apprenticeship, LPP) that are meant to foster curiosity, openness to new ideas, and informed skepticism: making observations, building and sharing ideas, coming up with questions that can be investigated (taken from NRC, 1996, AAAS, 1993 and Chinn and Malhotra, 2002). We are creating multiple, interrelated case studies (Yin, 2003) of students' participation by combining evidence from logfiles with data from pre-and-post measures, performance assessments, and -- in the case of ten students -- pre-and-post interviews. Prior to the implementation, we asked the teacher to rate their expectation of students' successes and motivation in the project. These indicate, at a rudimentary level, how the teacher perceives the student is participating in the class overall prior to the MUVE curriculum; in our case studies, this is compared to students' own perceptions (based on interviews and affective instruments) of their participation in the MUVE.

Findings and Conclusions

Interesting patterns about the types of learning processes and behaviors of students are emerging from the data. We are finding that the simulation fosters behaviors that are characteristic of situated learning and authentic inquiry. Limited by space, we briefly illustrate two. Further findings will be discussed in our presentation.

First, research has shown that students often do not engage in authentic science inquiry in schools (Chinn & Malhotra, 2003). However, we found numerous examples of students reasoning scientifically, making sense of causality, and building off each other's knowledge. The following excerpt presents one such example:

Cabra: a lot of people at the hospital have stomach pains and diarrhea
Rock: humm.. I think it might be a virus / bug

Rock: I'm sure of it,,, because a lot of people I have visited are coughing,,, and they sweat at night (might be a fever)
Cabra: yeah, and there are coughs too
Rock: yeah, it's probably a virus… temporarily, we'll call it that… okay??
Cabra: fine, but I got to do more water testing

Second, while research documents that learning and cognition is distributed, very few opportunities exist to document the kinds of informal supports students offer each other in the classroom. We are finding that students who do not typically participate in class, like Theo, provide help and support to others via increased participation:

Theo: hey lets meet at the school
Ri: WHERE IS THE SCHOOL
Theo: look at the things in the tool box then click the globe and click school
Theo: click river city map in the lower right hand corner

Our logfiles also document when students fail to reason scientifically, build knowledge, and offer supports. We are building cases of unrealized learning that suggest design heuristics to support situated and authentic inquiry.

Overall, MUVEs are a promising way to create situated learning experiences within K-12 education and to assess the complex forms of individual and group learning that ensue. In particular, the rich logfiles they generate provide scholars and teachers with detailed data to understand learning processes, to diagnose suboptimal patterns of student performance, and to assess the knowledge and skills students have mastered. In turn, this information can inform improvements in curricular design and develop insights about theory. Our design-based research illustrates early steps towards developing robust methodologies for studying situated learning under controlled conditions in which principled variations can yield knowledge about how context shapes collaboration and knowledge building.

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Using Social Network Analysis to Highlight an Emerging Online Community of Practice

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Abstract: In this exploratory study, Cocciolo, Chae and Natriello investigate the extent to which the communicative processes exhibited within a large digital repository illustrate the emergence of an online community of practice (CoP). In order to make this claim, we present a method for identifying the emergence of an online CoP using Social Network Analysis (SNA) on communication data (i.e., uploads and downloads) and institutional role (i.e., expert/faculty vs. novice/student). The analysis reveals that the online repository provides opportunities for novices to perform the role of the expert knowledge facilitator. We posit that these conditions constitute a necessary element for the emergence of an online CoP.

Introduction

In September 2006, Teachers College, Columbia University launched PocketKnowledge (PK) (http://pocketknowledge.tc.columbia.edu/) a digital repository for archiving and publishing the "knowledge products" (e.g., publications, working papers, research data, audio, video) of faculty, students, staff, and alumni. Informed by the literature on communities of practice (Lave & Wenger, 1991; Wenger, 1998), PK was purposively developed to facilitate the sharing of intellectual materials and collaboration among various members of the Columbia University (CU) community. Specifically, features such as: 1) group pockets/portfolios, 2) community commenting, 3) distributed/non-authoritative taxonomic intersections, 4) Rich Site Summary (RSS), and 5) variegated item-level access permissions were incorporated into the design of the system in order to encourage collaboration.

In this exploratory study, we analyze PK utilization by different members of the CU community (e.g., faculty, students) in order draw attention to the possible emergence of an online community of practice (CoP). In the context of this initial study, an online CoP refers to a group of people separated by time and location who: 1) share a common interest in some topic, 2) engage in a process of social learning, and 3) provide opportunities for the novice to perform the expert role (Johnson, 2001; Lave & Wegner, 1991; Wenger, 1998). Using Social Network Analysis (SNA) (Wasserman & Faust, 1994) and cutpoint analysis techniques (Hanneman, 1997), we construct a method for identifying the emergence of an online CoP, and examine the (sub)networks and interactions that have emerged thus far in PK.

Literature Review

The literature on collaborative learning has called for greater research emphasis on the "communicative processes involved in successful (and unsuccessful) peer interactions rather than just learning outcomes" (Cho, Steganone, & Gay, 2002, p. 43). According to scholars such as Lave and Wenger (1991), this line of inquiry is critical because learning is fundamentally a socially situated process. One method for analyzing communicative processes is the investigation of structural locations within a system using social network analysis (SNA). SNA has been used to shed light on several Computer Supported Collaborative Learning (CSCL) contexts. For example, SNA has enabled researchers to identify central and peripheral actors in a CSCL course. Moreover, it has elucidated how the actors' positionalities mediate "learners' perceptions and behaviors related to community-based information sharing practice" (p. 49). Other researchers such as Reffay & Chanier (2003) have investigated the influence of group cohesion in Computer Supported Collaborative Distance-learning (CSCDL). Others have used SNA to clarify the impact of social structures on knowledge construction in an asynchronous learning environment (see, for e.g., Aviv, Erlich, Ravid, & Geva, 2003).

Despite the insights that SNA affords, there are a number of concerns regarding the scope, depth, and richness of network data (de Nooy, Mrvar, and Batagelj, 2005). To address this concern, Martínez, Dimitriadis, Rubia, Gómez, Garachón, & Marcos (2002) augmented their SNA with qualitative research to gain a deeper understanding of a CSCL environment. Future iterations of this study will similarly employ qualitative methods to supplement the network analyses.

Methods

In the context of this mini-study, we used Systems Theory to define the uploading and downloading of materials as “communicative acts,” PK users as “actors,” and the cumulative communicative exchanges as “interactions” (Buckley, 1967). Although this is only one configuration for evaluating sociality (1), this particular systems arrangement is useful because it provides a readily available metric for assessing actors’ interactions within a network.

PK usage data was gathered from September 6, 2006 to November 18, 2006. During this time, N=228 distinct users exchanged files either by uploading a file or by downloading a file. The analysis does not include downloads from users who were not logged in. The usage data was converted to a matrix and visualized as a network using NetDraw (Boragatti, 2002). Network attribute data, which indicated institutional role (e.g., masters-level student) and color, was added to indicate user/node role. Additional analyses were conducted with NetDraw, including segmenting the network into components and filtering out key actors using cutpoints analysis. Table 1 presents the distribution of individuals over the set of institutional roles.

Table 1: Role distribution of user population

Library	Doctoral Student	MA Student	Faculty/instructor	Staff	Other
2	66	106	17	11	25

Results

The network can be decomposed into several components as shown in Figure 1. These include: 1) isolated actors (users who only use the system to store their own work and choose not to share with others), 2) a large and varied community of actors and interactions, and 3) close-knit communicators who are isolated. Within the large community of actors and interactions, there are two clusters. These can be found by visual inspection or by computing eigenvetors. Cluster one illustrates interactions for a course offered by a doctoral student, and cluster two illustrates interactions around library-contributed materials (e.g., historical dissertations). These two clusters illustrate the importance of community members who are specifically responsible for communicating knowledge or content (in this case, an instructor and an academic library).

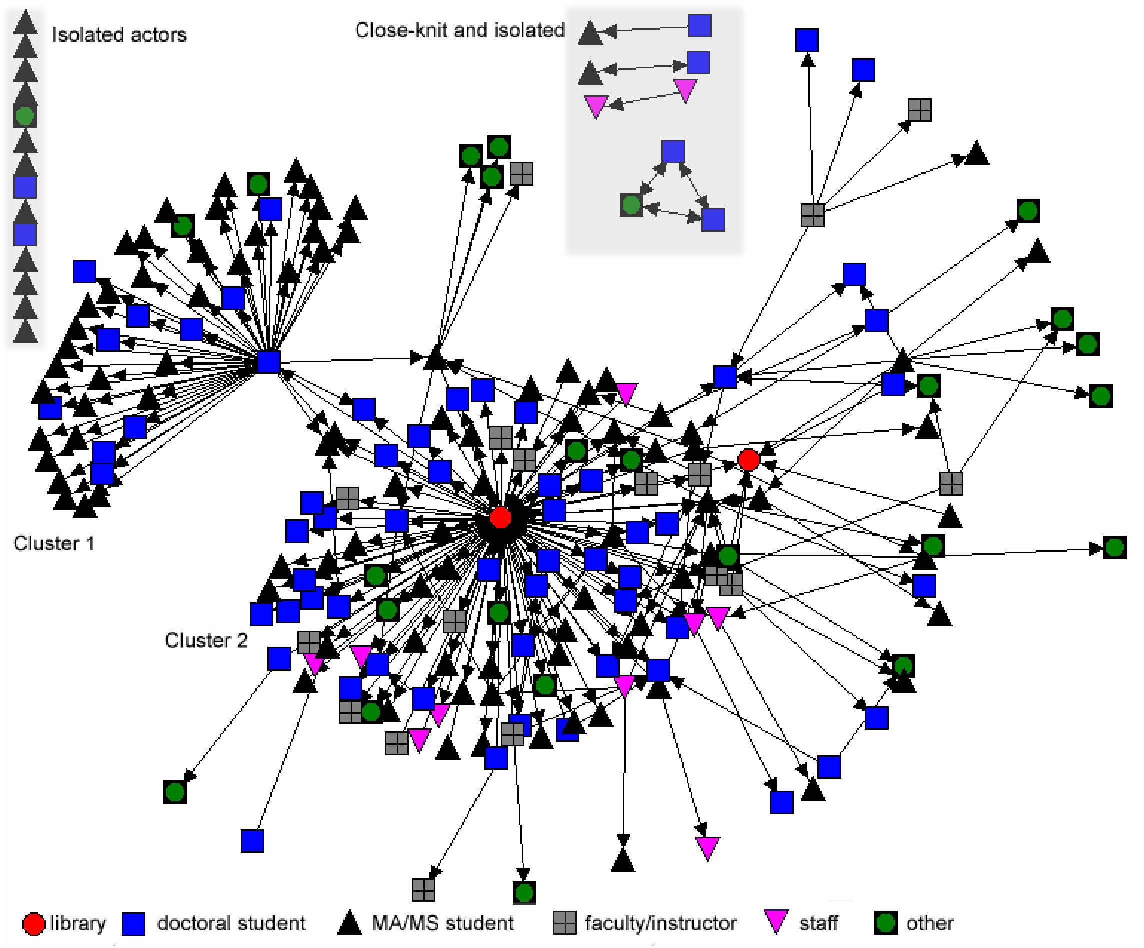

Figure 1. Components of community network visualization

Upon further analysis, there are many more critical community members than Figure 1 might suggest. A cutpoints analysis was conducted to reveal those key actors/nodes whose removal would leave the network divided into unconnected systems. As described by Hanneman (1997), "cutpoints may be particularly important actors -- who may act as brokers among otherwise disconnected groups." Figure 2, which shows the cutpoints or key facilitators, reveals that there are other actors—in addition to those highlighted in Figure 1—who play a significant role in knowledge sharing.

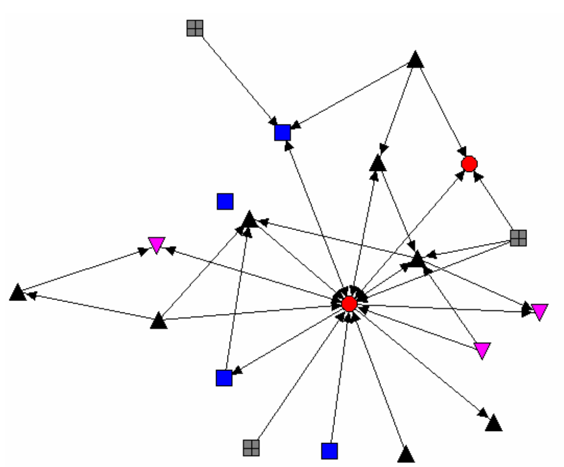
Figure 2. Cutpoints, or key facilitators of sharing

In the context of this study, cutpoints are actors who are facilitators of knowledge sharing. This analysis reveals that knowledge facilitators occur in proportion to their total numbers within the system. For example, ~11% of all cutpoints are faculty, and ~7% of all actors are faculty. Similarly, ~72% of all cutpoints are students, where ~75% of all actors are students (see Table 2). Our analysis also reveals that students (i.e., novice) play an equally important role in facilitating knowledge sharing as do faculty (i.e., experts). Moreover, the analysis indicates that novice learners (in a relative sense) are able to come to occupy the role of the expert facilitator, gradually "fashioning relations of identity as a full practitioner" (Lave & Wegner, 1991, p. 121). Much like a CoP, experts are not dispensed with, but rather novice learners are provided "with opportunities to make the culture of practice theirs" (p. 95).

Table 2: Cutpoints (or key actors) by role, % of all cutpoints, and % of all users

	Library	Doctoral Student	MA Student	Faculty/instructor	Staff	Other
Cutpoints	2	4	9	2	3	0
% of all cutpoints	11.1%	22.2%	50.0%	11.1%	5.6%	0%
% of all users	.9%	28.9%	46.5%	7.5%	4.8%	11.9%

Conclusion

This study used Social Network Analysis (SNA) to examine the communicative processes represented in an expansive repository for community-generated intellectual materials. This analysis reveled several phenomena, the most important of which is the extent to which novice learners have come to occupy central roles in terms of facilitating knowledge sharing. Additionally, by examining the extent to which novices are afforded opportunities to share the role of the expert performer, and analyzing the proportion of expert and novice actors who share the role of knowledge facilitator, the study presents a way for researchers to determine the emergence of an online CoP.

Endnotes

(1) Another measure of sociality could be community commenting on materials within PK

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Mentored Professional Development to Support Successful Integration of Technology-enhanced Science Curriculum

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Abstract: MODELS (Mentored and Online Development of Educational Leaders for Science) is a 5-year NSF grant funded to support teacher professional development and learning to enable schools to implement technology-enhanced inquiry instruction. In this paper we discuss professional development activities, classroom enactment of technology-enhanced projects, and the trends emerging in changes in teachers' beliefs and practices during the first two years of the project. We present a case study of one teacher's learning progression and discuss plans for further data collection and analysis.

Inquiry-based science learning and teaching can be enhanced by the use of technology in the classroom (Bransford, Brown, & Cocking, 1999; Linn, Davis, & Bell, 2004). However, integration of inquiry-based science curricula and technology integration is difficult for many teachers. Effective professional development programs that are flexible to adapt to the needs of teachers, schools, and communities (Borko & Putnam, 1995) and are sustainable contribute to successful integration (Davis, 2003; Fishman et al., 2003; Grossman, et al., 2001; Little, 2002).

MODELS, Mentored and Online Development of Educational Leaders for Science, is a 5-year NSF grant funded to support teacher professional development and learning. The program was designed to enable schools to implement technology-enhanced inquiry instruction by means of a sustainable professional development program that is customized to their needs. MODELS aims to improve both science understanding and practice of teachers through the development of peer-mentoring communities. Teachers and mentors receive professional development opportunities at summer workshops and mentor meetings and are encouraged to discuss their experiences in face-to-face and online collaborative activities. Activities are designed to support teacher collaboration, to stress reviewing student work, and to support teachers' customization of the curriculum and their teaching. We are in the second year of this 5-year grant, and are examining how teachers' beliefs and practices are changing from Year 1 to Year 2 as a result of the professional development.

Methods

Participants

Participants include 18 middle school science teachers from two schools in separate districts who are integrating technology-enhanced projects into their curriculum.

Learning Environment

Teachers use projects created in the Web-based Inquiry Science Environment (WISE) a free online science learning environment for middle and high school students (wise.berkeley.edu). Projects engage students in various collaborative activities, such as designing solutions to problems, debating science topics, investigating hypotheses, and critiquing scientific claims.

Data Sources

Summer Workshop Teacher Comments

During each summer workshop teachers responded to questions posted online that asked them to reflect upon the professional development activities, their teaching and learning, the implementation of the projects during the upcoming year, and future professional development activities that could be useful.

Classroom Observations

University researchers observe teachers and students at various times when teaching with a WISE project. Observations are recorded on an observation form containing specific categories: general interactions, working with simulations, small group interactions, and mentor support.

Teacher Interviews

Following the completion of each project, university researchers interview teachers about their experiences. Questions focus on connecting ideas between the project and the rest of the curriculum, teaching with the models/simulations, effectiveness of teachers' customizations, assessment/feedback to the students, and types of mentoring/support received and wanted for the next WISE project.

Procedures

Year 1

During the summer, teachers attended a workshop for 5 consecutive days on the university campus. Teachers were introduced to WISE projects, they selected projects to run in their classrooms, and they planned and set goals for teaching with the projects during the upcoming year.

During the school year, all teachers ran at least one WISE project in their classroom. A university-based mentor was present during the first day to offer support and to help the teachers get started and often provided additional support during subsequent days. One teacher who had previously run WISE projects in her classroom acted as the school-based mentor for School 1. She visited teachers' classrooms when her schedule permitted and provided technical support to the teachers. She often acted as a liaison between the teachers, the administration, and the university researchers. All teachers from School 2 were new to WISE projects, so they relied on the university mentors rather than school-based mentors for support.

Year 2

Teachers attended a summer workshop for 5 consecutive days on the university campus. Teachers reviewed their previous year experiences with WISE projects, discussed teaching practices, and selected and customized projects to be used the following year. The university researchers provided teachers with samples of student work and prompted teachers to use this data to make evidence-based decisions about changes in teaching practice and project customizations. Researchers also led discussions about teaching strategies for teaching with models and successfully integrating projects into the larger curriculum.

The school-based mentor from School 1 remained the same, and a mentor was selected for School 2. Mentors met for 2 days on the university campus. They reviewed WISE projects, discussed teaching and mentoring strategies, shared WISE experiences, and planned for the upcoming school year.

17 of the 18 teachers have run or are scheduled to run more than one WISE project in their classroom in Year 2. The school-based mentors are meeting with teachers before and/or during project runs to offer assistance. They provide the majority of support for the teachers at their school while university researchers support the school-based mentors, but are available to provide support to teachers if requested. The mentors continue to act as liaisons between the teachers, administrators, and university researchers.

Preliminary Results

Preliminary analyses of summer workshop data, classroom observations, and teacher interviews reveal some emerging trends in changes in teachers' beliefs and practices. We use one teacher, Rachel, as a case study to provide examples of these emerging trends and to demonstrate her learning progression.

Data reveal that on average teachers are more confident Year 2 using the technology. During the first year, teachers relied on university researcher support to use the technology on the first day and when troubleshooting technical issues. Teachers worried about if the technology would work and their abilities and their students' abilities to use it correctly. During a post-run interview in Year 2, Rachel commented:

> Last year and a little bit this year also, I was more concerned about the mechanics of it, of the programs and which button do they push, what the screen looks like, scroll down and save your work. And I feel like they're getting the hang of it. I feel like next year I don't need to stress that as much and now I know which concepts I need to stress…We can talk more about what we're teaching than the I-Books. Now we're using it (the technology) more than focusing on it. I mean it's exactly the way the evolution should be.

In Year 2 teachers are able to focus more on the science content, students' understanding, and their teaching practices rather than on the technology. Rachel recognizes this as a natural learning progression.

In general, in Year 2 teachers are better able to use student work to inform their teaching practices. This was something that was prompted at the summer workshop, and Rachel reported, "I liked having the time to really think about how well my students integrated the ideas in the mitosis project. It was helpful to have time to discuss the data with Danielle and come up with ideas about where the gaps are. We have revised the project, and made a plan for how to change the way that we teach it." She also stated in a post-run interview that "going the second time is so much better because I know exactly where they're going to have problems and where they're not going to have problems." The teachers were able to use the evidence provided in their students' work to determine where the students had trouble understanding the content and made plans on how to account for these challenges.

Teachers also demonstrated much more use of student work *during* project runs to inform their teaching. During Rachel's Year 2 post-run interview she revealed, "last year on this project I may not have even done openers. I don't think I was doing openers except for if I felt like I really needed one…this year I did them most of the days." This year Rachel made it a priority to look at student work several times during the project run to determine her students' understanding. She created openers, which were daily discussion questions or topics related to what she found her students were having trouble understanding. She said,

> I create the openers after I've looked at the work. And I designed them to try to correct misconceptions or help them with something that they're struggling to understand. I don't know that I'll use the same openers myself next year. It all depends on where they are. What point did they get to in the project that day and then that night I'd look at it and what kinds of issues are they having…I feel like it's important, but I feel like they're useless unless you're catering them to exactly what the kids need at that point.

This reveals that Rachel has learned the importance of evaluating student work during project runs to assess students' understanding, so that she can provide the guidance needed to grasp the science concepts.

These preliminary results are promising and suggest that the professional development is contributing to positive changes in teachers' beliefs and practices. Additional teachers will be observed and interviewed during Year 2 and compared to Year 1 data, which will also allow us to create teacher trajectories that can be tracked over time and compared across settings. We will share these additional findings at the conference and facilitate a discussion on designing collaborative professional development opportunities to support successful integration of technology-enhanced curriculum.

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A Theoretical Framework of Collaborative Knowledge Building with Wikis – a Systemic and Cognitive Perspective

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Abstract: Wikis provide new possibilities for collaborative knowledge building with artifacts. This paper presents a theoretical framework for describing and understanding the processes which lead to collaborative knowledge building. The model borrows from the systemic approach of Luhmann as well as from Piaget's theory of equilibration. It describes people's learning activities as processes of externalization and internalization. Individual learning happens through internal processes of assimilation and accommodation, whereas changes in a wiki's information space are due to activities of external assimilation and external accommodation. All these equilibration activities are caused by subjectively perceived differences between an individuals' knowledge space and the wiki's information space. Differences of medium level are considered to cause cognitive conflicts which activate the described processes of equilibration.

Computer-Supported Knowledge Building with Wikis

Recently, a variety of new tools fostering computer-supported collaborative learning (CSCL) and computer-supported cooperative working (CSCW) appeared and established themselves on the WWW. On the one hand, the term Web 2.0 describes a set of new interactive technologies and services on the internet. On the other hand, Web 2.0 refers to a modified utilization of the internet. What is of particular importance in the web 2.0 context for CSCL researchers is the integration of so-called social software (Kolbitsch & Maurer, 2006). Social software refers to systems which facilitate human communication, interaction, and collaboration. These systems support the constitution and maintenance of self-organizing social networks and communities. Weblogs (blogs), file-sharing communities, and especially wikis loom large in this social-software context. Blogs are websites which are used as online diaries. They contain new entries periodically. Usually, blogs are produced by a single author or by a small group of users. But they are open to the public for reading (Blood, 2002; Maurer & Tochtermann, 2002). File-sharing web pages provide private spaces where users can store their documents and a public space where files can be shared with other users. Popular examples of file-sharing communities are services like flickr (a photo sharing website), or youtube (a video sharing website) (Rodriguez, Tan, & Gkantsidis, 2005).

Whereas blogs and file-sharing systems are mainly used for pooling information, wikis have special potential for computer-supported collaborative knowledge building. Wikis are web sites which allow users not only to have access to its content but also to change the content online (Leuf & Cunningham, 2001). Wikis are mostly used to write texts. Their special feature is that people can do all kinds of revision of the text: they can create hyperlinks and fill them with text, they can revise texts by adding, deleting or changing any text parts they want to. This way, large groups of like-minded people are able to work collaboratively on one and the same text about a certain topic. In wikis all users collaboratively create one hypertext. An example which illustrates the potency of wikis is the online encyclopedia Wikipedia. Here, users mutually develop the world's largest encyclopedia. Every internet user is allowed to take part in this undertaking. The Wikipedia example will be applied throughout the whole article in order to make our theoretical analysis more concrete. In a wiki people work mutually on one common artifact (cf. Stahl, 2002 for the relevance of artifacts in CSCL). And a multitude of people around the world are able to participate in this process anywhere, anytime. In this article we will ask what makes wikis especially attractive for learning purposes and knowledge building. To examine this question, we will consider several fundamental perspectives on learning and knowledge building. We presuppose that a person's individual knowledge is a resource for other peoples' learning (Kafai, 2006; Scardamalia & Bereiter, 1994). We base our arguments on findings as to how people make use of each others' knowledge through collaborative knowledge building with artifacts (cf. Bruckman, 2006). We rely on Papert's approach of constructionism (e.g. Papert, 1980, 1987, 1993, 1997; cf. also Kafai, 2006) and point out that our perspective is grounded in a tradition that emphasizes the learner's activity in the learning process (cf. Greeno, 2006)

In the remainder of this article we will present our model of collaborative knowledge building with wikis by taking a systemic perspective and by distinguishing between the processes of externalization and internalization. We will clarify these processes by continuously applying the Wikipedia example to our model. We will then describe the four processes of knowledge building that result from the distinction between external and internal (cognitive) processes on the one hand and between assimilation and accommodation on the other hand. Finally, we will describe the motivational aspects of collaborative knowledge building. We are aware that, in the strict sense, the motivational aspects are the foundation of the processes of knowledge building. The cognitive and socio-cognitive processes cannot be separated from the motivational ones. However, we decided to present our model in an order which would make clear that the cognitive and socio-cognitive processes can help to explain the motivational processes.

A Model of Collaborative Knowledge Building with Wikis

In the model presented here we consider from a systemic point of view the components and the processes necessary for the exchange of knowledge and for collaborative knowledge building with wikis. For this purpose we borrow perspectives from systemic approaches (cf. Luhmann, 1984, 1995, 1997; von Bertalanffy, 1950, 1968). Based on these perspectives, a wiki can be seen as a *social system* which operates through the communication of people sharing information and creating artifacts. We have to make clear here that according to Luhmann, the people themselves are not part of the social system. With respect to a wiki, this is obvious because the wiki and its content exist as an artifact even if all users are absent. *Cognitive systems* operate through cognitive processes like retrieval of knowledge from long-term memory (Baddeley, 1986, 1992), elaboration of knowledge (Craik & Lockhart, 1972), or externalizing and internalizing information. According to Luhmann (1984) it is the social system's border and the difference between system and environment which defines a system. The difference between a system and the environment is determined by the system's way of operating. Thus, clearly delineating the "border" between the social system (the wiki) and cognitive systems (the users) is crucial for understanding how collaborative knowledge building with wikis works.

In this section we will first of all outline the functionality of the social system, then we will address the functionality of the cognitive systems. After that we will describe the processes responsible for transitions between the social system and the people's cognitive systems. Here, we distinguish the process of externalization from the process of internalization.

Social and the Cognitive Systems

According to Luhmann (1995) a social system operates via communication. With respect to Wikipedia the community of users establishes itself through the interaction of its participants who use their knowledge and write encyclopedia articles. The wiki articles comprise the information people share. For example one user might know something about George Washington's childhood and contribute this information to a Wikipedia article about George Washington. Another user might contribute something about Washington's attitude towards slavery and so on. This way, the George Washington article develops out of provided information and becomes more and more complete. The articles are traceable in the internet. There they are accessible for all members of the community. Each member of the community can contribute to an article. On the one hand, she or he can extend or diminish an article by adding or deleting information (e.g. adding references about George Washington). On the other hand a participant can change the artifact's structure by revising an article (e.g. removing biographical information about George Washington at the opening of the article and moving the references to the end). The information which is embedded in the wiki builds the wiki's "information space". It consists of all information units (definitions, descriptions etc.) and relations or links between these units. Information units and relations between them belonging together make the structure of a wiki.

Turning to the cognitive systems, we analogously describe each group members' individual knowledge as his/her individual "knowledge space". This knowledge space contains all the schemas a person possesses (Bartlett, 1932; Piaget, 1970; Schank & Abelson, 1977). A schema is made up of knowledge units and relations between these units belonging together. For a person contributing to a Wikipedia article about George Washington, knowledge units might be Washington's birthplace, birthday, the name of his mother, and so on . What processes are going on, when people share their knowledge by creating wikis? What happens when people work parallel on one common artifact, thereby building new knowledge collaboratively? Here, two processes are relevant which describe the "crossing of the border" between the social and the cognitive system (a process which Luhmann terms *structural coupling*): we refer to these processes as "externalization" and "internalization" respectively.

Externalization

For contributing to the development of a wiki a person first has to externalize his/her knowledge. He/she does this by writing information down in the wiki which reflects parts of his/her own knowledge space. For it, knowledge units of one's own knowledge space have to be conveyed into a wiki article which maps the person' knowledge. For describing these processes of externalization we refer primarily to an individual's declarative knowledge in her/his memory's semantic system (Tulving, 1985).

This artifact, then, exists independently from the person who created it, and it contains information units which follow from the person's knowledge units. The information units in the wiki's information space relate to the knowledge units of the contributor's individual knowledge space: therefore, the person's cognitive schemas are represented by the wiki's structure. E.g. if a Wikipedia user writes something about George Washington's military career, he/she can only write down something which was in his/her knowledge space before. The person's knowledge about George Washington's military career precedes the information about George Washington's military career in the wiki's information space. In this way, information about the military career is significantly related to the person's knowledge about the career. Of course, the information in the wiki and the knowledge in a person's mind are not identical, but they are equivalent to a certain degree. After the process of externalization, the artifact's information space exists independently from the person's knowledge space.

Contributing to an article does not only allow the creation of an artifact, it can also lead to an individual learning process of the contributor. The mental effort necessary for the externalization of knowledge can extend the person's individual knowledge space, because externalization requires deeper processing and clarification. This aspect is addressed by the work of Flower and Hayes (1980) as well as Webb (1982). So, normally the person who produces a wiki article cannot externalize some of his/her own knowledge units without some changes of his/her own individual knowledge space. Through the externalization process one often deepens one's own knowledge and might even acquire new knowledge which can improve an existing schema. So externalization can lead to individual learning processes, and a contributor to a wiki article can expand his/her individual knowledge space through acquiring new knowledge units which were not part of the individual's knowledge space before. With respect to the Wikipedia article about George Washington one can imagine that a person who writes something about George Washington's military career is forced to restructure her or his own knowledge in order to make it more comprehensible for others. This way some issues become clearer to her-/himself and he/she acquires deeper knowledge and comes to new insights about George Washington's military career.

In Figure 1 this kind of learning is shown by the grey symbols which expand the individual knowledge space K to K'. In this figure each symbol represents another knowledge unit. Each of the three people externalizes knowledge by contributing to the wiki, but only Person 1 and Person 3 acquire new knowledge units by this activity.

If a person has contributed to a wiki, then each individual group member can have access to the wiki's information space. This is shown by the symbols in the wiki's information space in Figure 1. For the time being, this process of externalization does not require the interaction with other people in a narrow sense. A person can externalize her/his own knowledge (and thereby extend one's own knowledge space) without necessarily addressing other people. However, with respect to the process of internalization, which will be described in the next section, a participation of other people is indispensable.

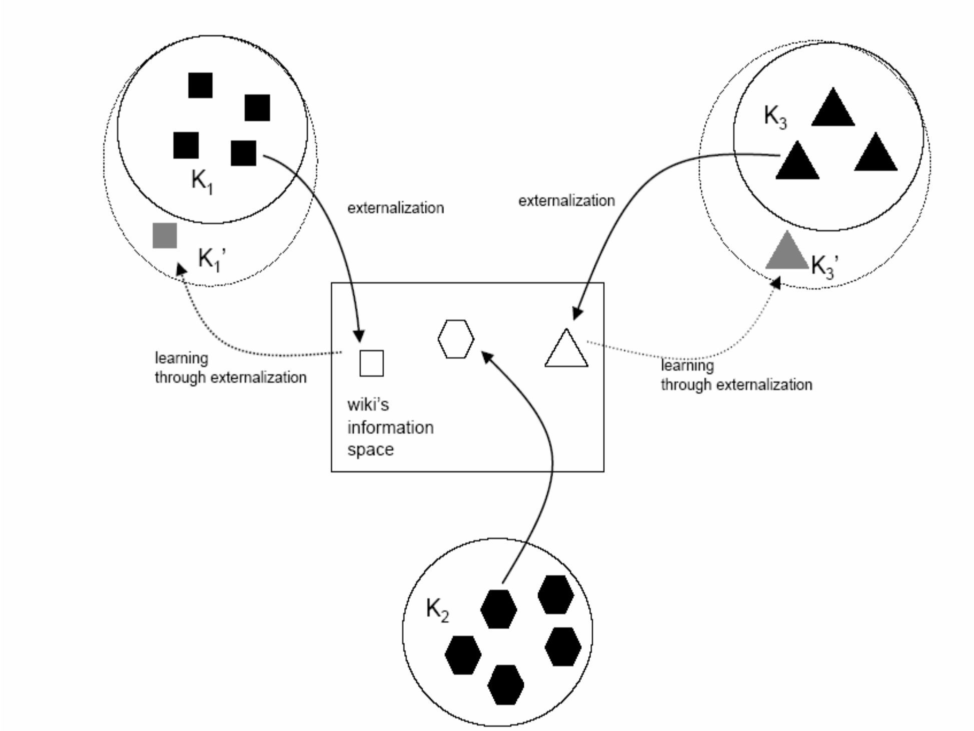

Figure 1: Three people with different individual knowledge spaces K_1 to K_3 interacting with a wiki. The grey symbols show novel knowledge units as a result of learning through externalization, K_1' and K_3' represents the extended knowledge spaces correspondingly.

Internalization

Interindividual knowledge transfer and collaborative knowledge building takes place when people have the opportunity to work with a wiki and to internalize the information the wiki contains. So people have to decode the information captured in a wiki, and then they have to integrate the information units in the wiki's information space into their individual knowledge spaces. Through this internalization a person acquires new knowledge units and relations between knowledge units, i.e. a person uses the wiki's information space to expand his/her own knowledge space. In Figure 2 the results of an internalization is indicated by the striped symbols. Through internalization the individual knowledge spaces are expanded to K''. For example, if a person reads something about George Washington's first election as president and this person did not know beforehand that George Washington became president in 1789, then the person expands his/her own knowledge space by adding this new knowledge unit to his/her schema about George Washington.

Besides this interindividual knowledge transfer resulting from the internalization of information in a wiki, an additional kind of knowledge-acquisition process can occur: If a person internalizes information units from the wiki which did not belong to his/her personal knowledge space before, knowledge units can develop which were neither part of his/her personal knowledge space nor part of the wiki. Such additional knowledge acquisition can happen if a new knowledge unit that a person internalized from a wiki interacts with his/her individual knowledge space in a way that enables the person to create new knowledge. This kind of knowledge building can happen if a person is able to infer new knowledge units out of the knowledge units he/she internalized through the work with the wiki and the knowledge units he/she had in his/her individual knowledge space before. This knowledge can be described as "emergent knowledge". A person would not have been able to create this knowledge if it had not been internalized from the artifact before. This emergent knowledge is a product of the collaboration and as such represents the result of a form of collaborative knowledge building which is more than mere knowledge sharing (something qualitatively new is developed). Emergent knowledge has not been part of the individual's knowledge spaces before (for a detailed elaboration on the phenomenon of emergence cf. Holland, 1998 or Johnson, 2001). This process can also be clarified with the Wikipedia example:

if a person comes to know that George Washington became president in 1789 by reading the corresponding Wikipedia article, and if this person previously knew that the U.S. declared independence in 1776 and also knew some facts about the American Revolutionary War, he or she can draw conclusions with repect to certain delevopments in American history. In Figure 2 person 3 has created such emergent knowledge.

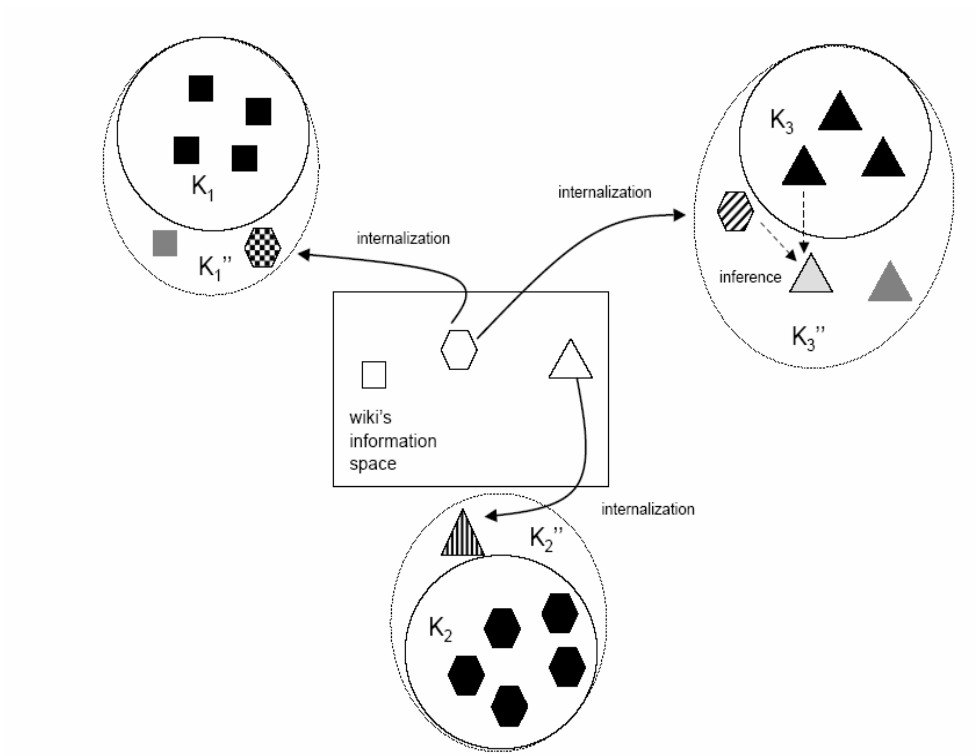

Figure 2: Process of internalization: Each of the three individuals internalizes one concept (striped symbols). Person 3 additionally creates a new knowledge unit (light-grey) through a process of inference from an internalized knowledge unit and from another one belonging to the person's knowledge space previously. The occurrence of such knowledge units shows an emergent process.

Four Processes of Knowledge Building

The model so far has described different kinds of individual learning. Individual learning occurs

- as a result of externalization (due to processes of deeper processing and elaboration which are activated by the externalization process),
- as a result of internalization (due to the simple adding of new knowledge units) and
- as a result of inferences (due to the expansion of a person's individual knowledge space through internalization and, arising from that, an opportunity to interconnect old and new knowledge units, i.e. inferences of knowledge units that were unknown until then).

All forms of learning take place when people interact with the artifact in a way that information and knowledge are transferred between the individual's knowledge space and the wiki's information space. So, to refer back to Luhmann's perspective, learning occurs by the transgression of the border between the individual's knowledge spaces and the wiki's information space. The processes of internalization and externalization cause these individual learning processes. But in the model as described so far, learning primarily is considered as quantitative increase of knowledge units in an individual's knowledge space. And up to this point, expansion of the wiki's knowledge space has been described, but not yet qualitative changes within the wiki. These aspects will be addressed systematically in this section.

For considering this qualitative aspects we take up Piaget's model of equilibration (Piaget, 1977a, 1977b). This model also describes how people deal with new information from their environment and how they perceive and encode this information from outside and integrate it into their own cognitive schemas. The equilibrium theory describes the way people try to maintain a balance between the environmental information on the one hand and their cognitive schemas on the other hand. If information is new and leads to knowledge that was not part of the individual's knowledge space before, it cannot be promptly decoded and integrated into an existing cognitive schema. Thus, people have to adapt to this new environment. There are two possibilities of adaptation: people can *assimilate* the new information or they can *accommodate* their internal cognitive schema (in order to match it with the information). Assimilation describes a process where an individual understands new information on the basis of an existing cognitive schema and then integrates it into this cognitive schema. This means that information coming from the environment is perceived and modified in a way that makes it fit into the individual's cognitive schemas. Assimilation describes more a *quantitative* aspect of individual learning. The mental schemas of an individual remain the same and only additional concepts are acquired which fit to these schemas.

The other process of adaptation which Piaget describes is the process of accommodation. Here a person interacts with new information in a way that changes a cognitive schema. In this case, a person does not simply integrate new information into an existing cognitive schema, but actually changes this schema in order to better understand the environment and its information. We consider the creation of new schemas as an indicator of learning in a more qualitative manner.

We apply this distinction between assimilation and accommodation to our model of people's interaction with wikis described in our model. When interacting with the wiki, people can learn as a result of externalization, or as a result of internalization (with or without inferences). This learning can take place by assimilation or by accommodation respectively: people can acquire new information without changing their cognitive schemas, or they can modify schemas or create new schemas.

For collective knowledge building with wikis, we state that accommodation and assimilation do not only take place internally (in people's individual knowledge spaces) but also externally (in the wiki's information space). A wiki can accommodate or assimilate as well. If people contribute information to the wiki without linking it to previously existing information units, they only extend the wiki by adding some information. If people contribute this way, the information space of the wiki assimilates the new information, which means that the structure of the wiki remains the same, only some information is added. For example, if a user adds some references about George Washington in the Wikipedia article, this is only an assimilation of the wiki. But the wiki can also accommodate. This happens when people do not only attach new information to the existing information space, but they also structure the information of the wiki in a new way. For example, in Wikipedia this would happen if a user revises an existing article by arranging and configuring the information of the article, by separating an article into different articles, or by linking an article to another one and describing the relation between both. In Wikipedia such organization processes often occur. The application of a history flow diagram is a visual method developed by an IBM research group which makes such activities visible (Viegas, Wattenberg & Dave, 2004). Such visualizations of Wikipedia articles show that sometimes people only add new information to in existing article, and sometimes people completely restructure an article.

In sum, in collaborative knowledge building with wikis we can distinguish four different forms of knowledge building: Internal assimilation (quantitative individual learning), internal accommodation (qualitative individual learning), (quantitative) external assimilation, and (qualitative) external accommodation. The first two are processes of individual learning, the latter two are processes of a collaborative knowledge building with respect to the wiki.

Motivational Processes in Knowledge Building

What motivates people to engage in this collective process of knowledge building? We know from many scenarios where shared databases, forums, or blogs are used for knowledge exchange that people often are reluctant to contribute their own knowledge (Ardichvili, Page & Wentling, 2003; Huber, 2001; Jian & Jeffres, 2006) because of the costs of the contribution: People have to write down information, they fear embarrassing themselves through publishing information which might contain mistakes, or they may be afraid of losing power if they share information, which only they have (Cress & Hesse, 2004). All these problems are described in knowledge-exchange settings, where the main aim is to pool information and to make it accessible (Cress & Hesse, 2006). In knowledge building scenarios like Wikipedia this seems to be different. The success and quality of this encyclopedia shows that people take part in this collaborative process of knowledge building voluntarily and with plenty of effort and enthusiasm. What motivates people to do this?

Following Piaget's model of equilibration we propose that people engage in knowledge building by contributing new information to wikis and by restructuring existing articles because of a *social-cognitive conflict*. We propose that when people work with a wiki they have to match their own individual knowledge space with the information space the wiki provides. This matching process can lead to different results: If an individual feels that the wiki's information space is congruent to his/her individual knowledge space then there is no need for equilibration and people do not accommodate or assimilate, either internally or externally. In contrast, if people feel that the wiki's information space differs from their own knowledge space, there is a need for equilibration, which people can satisfy by processes of internal or external assimilation or accommodation. If an individual realizes that concepts which are part of the individual's knowledge space are missing in the wiki he/she perhaps will externalize these and add them to the wiki (external assimilation). If she/he feels that the wiki's information space describes concepts which are not part of the individual knowledge space she/he will acquire new knowledge by internal assimilation. If she/he feels that both spaces are structurally different he/she will accommodate the cognitive schema (internal accommodation) or revise the wiki's structure (external accommodation).

We further propose that the motivation for the described activities of equilibration is a function of two features: The amount of dissonance between the individual knowledge space and the wiki's information space, and the *valence* which the topic has for a person. According to the valence we propose a linear relation: the higher an individual rates the valence of the topic, the higher the perceived cognitive conflict is and the more interest (Krapp, 1999) a person feels. According to the *objective difference* between the individual knowledge space and the wiki's information space we propose an inverted u-shaped relation between the difference between both spaces and the cognitive conflict people perceive which is displayed in Figure 3. If the difference between both spaces is very small, there is no need for equilibration. If the difference is very large, the concepts of the wiki and the individual knowledge space will not be perceived as describing one and the same topic. This will reduce the need for making both consistent. We propose that only a medium-level discrepancy causes a cognitive conflict which motivates people to engage in one of the knowledge building processes described above.

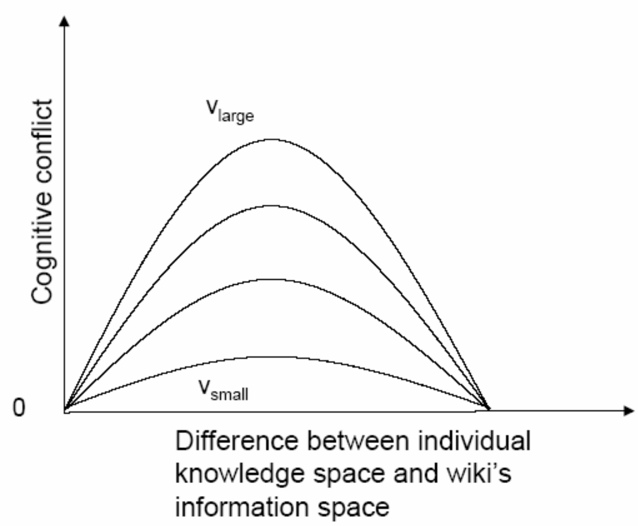

Figure 3: The inverted u-shaped relation between cognitive conflict and difference between an individual's knowledge space and the wiki's information space. The Figure provides this relation for four different levels of v, ranging from a low level of v to high level of v.

In this model the dissonance between people's individual knowledge space and the wiki's information space is the motor of the system's development. In a process of mutual development people learn and enhance their individual knowledge space and the artifact improves, becomes more exhaustive and more and more consistent. And according to Luhmann (1986) this is the base of the autopoietic processes which can be observed in all social systems (for a detailed elaboration on the phenomenon of Autopoiesis cf. Varela, Maturana, & Uribe, 1974 or Luhmann, 1990). Through processes of equilibration the wiki tends to incorporate more and more knowledge from the individual knowledge spaces of the users. Through external assimilation the wiki consists of more and more information units, and through accommodation processes it enables new understandings and transports new and emergent information.

Conclusion

In this article we develop a model which helps us to better understand collaborative knowledge building with wikis. For this purpose we combined Luhmann's system theory with Piaget's cognitive theory. Luhmann's approach is very thorough with respect to social systems, and Piaget's theory primarily focuses on the development of cognitive structures. Our model attempts to demonstrate the interplay of the social system wiki and individuals' cognitive systems. This consideration of the structural coupling of social and cognitive systems illustrates collaborative knowledge building with artifacts and might be a fertile approach for CSCL research. Our next steps will be to test the model empirically in various contexts in order to further elaborate on this approach and to make it more sophisticated.

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Impact of Anonymity of Input in Next-Generation Classroom Networks

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Abstract: This project looked at anonymity of input across a series of classroom activities seeking to answer three research questions. First, did activity type influence students' use of anonymity? Second, did activity type influence students' perception of the utility of anonymity? Finally, did student statements about the use and utility of anonymity match their actions? Analysis of the digital artifacts revealed no significant differences for use of names by activity or gender. Females more frequently made comments about wanting to be confident of their answers before they would attach their names. Males much more frequently expressed that anonymity was not important to them. Yet the use of names by the two groups across activities was virtually identical. Both groups had a use of names across all activities of approximately 60%.

Introduction

This project looked at anonymity of input across a series of four classroom activities done using a next-generation classroom network. Next-generation classroom networks have four important features. First, the networks allow for many different formats of input including free response. Second, the networks perform some sort of meaningful, synchronous input aggregation. Third, the networks display submitted data to the group in a contextually meaningful format. Fourth, the input device for next-generation networks is an able device (graphing calculator, computer, etc.) and not a multiple choice clicker. The three research questions this study explored were: First, did activity type influence students' use of anonymity? Second, did activity type influence students' perception of the utility of anonymity? Finally, did student statements about the use and utility of anonymity match their actions?

Changing What Anonymity Means

Webster's defines anonymous as "lacking individuality, distinction, or recognizability." (Merrian-Webster) Within next-generation classroom networks students are only anonymous in the public space. Public anonymity specifically refers to the ability of the participants to submit data to be viewed in the public display space in a way that identities are not revealed. In next-generation classroom networks, it is explicit to the students that their identities can be viewed by the teacher in the private space. The ability of student data to be viewed by the teacher is private accountability. The participants' identities are only hidden from other participants, not from the teacher.

There is a tendency to talk about anonymity as the ability to avoid negative consequences. It is seen as the removal of identity or the taking away of something. Teachers believe that anonymity, in the display space, will save students embarrassment. There is an expressed feeling that anonymity can save students from being made fun of by their peers (Davis, 2002a). This description of anonymity is subtractive. The individual is deleting their personally identifiable information from the group. Next-generation classroom networks allow for a positive view of anonymity. Anonymity allows for an extension of the students' private space. Private space is the space in which the student feels comfortable experimenting, trying out different types of input without having to take firm ownership of the idea to others (Stroup, personal conversation 2001). In their private space (scratch paper, graphing calculator, laptop, brain) students can work through difficulties, on the way to finding solutions or creating a hypothesis. Previous work in classrooms using next-generation networks indicates that the veil of anonymity extends this private space by allowing students to share (make available for class discussion) their nascent ideas without the fear of ridicule (Davis, 2002a, 2003a).

Anonymity opens the individuals' shared information via the class display for interpretation. For example, if there is a range of answers collected from the students up in the display space, students can talk about any one of the answers as if it was theirs. Or, they can talk about the response as if it was someone else's. It is specifically because the information in the display does not have names attached that students can "try on" other responses. In this way, anonymity opens up the classroom allowing students to try on new roles. Students having submitted a correct answer, if asked how someone might have gotten a different result, can try on being someone who got a wrong answer and explain how the incorrect answer might have been derived. Students can add on to who they are. They can add on to who they talk about and it is not antagonistic because they are not talking about the most popular kid in the classroom or the shy kid or themselves, just generically about the response. Within the network space, anonymity opens up new ways to participate in affirming ways. Anonymity becomes additive in that it adds to the roles students can play in the classroom and extends the student's private space.

Literature Review

In Education research, the predominance of research on anonymity of input has been done using asynchronous data collection (Cohen & Scardamalia, 1998; Hoadley & Linn, 2000; Hsi & Hoadley, 1997; Scardamalia & Bereiter, 1992). Major results from this field showed that anonymity of input allows for greater gender equity in peer collaborations. In the field of Business Communication research, systems allowing for synchronous data input have been the predominant focus (Connolly, Jessup, & Valacich, 1990; Gallupe & Cooper, 1993; Jessup, Connolly, & Galegher, 1990; Scott, 1999; Valacich & Dennis, 1992). The systems were created to do research on brainstorming in group settings. Major results from these studies showed that larger electronic brainstorming groups were more productive, in terms of participation and quality of input, than verbal brainstorming groups.

Methods

The research for this project was conducted in two pre-calculus classrooms (n=29) at an urban high school on the East Coast of the United States. First a framework by which to select activities was needed. Using the taxonomy for Generative Activities proposed by Stroup, Ares, Hurford and Lesh (in press-b), four activities were chosen that embodied characteristics from different categories in the taxonomy. First Questioning activities, these were situations were the teacher asked a question to check for understanding and students responded electronically. Second, was a connected SimCalc MathWorlds activity. Third was a NetLogo linear regression activity. Forth was the NetLogo Disease simulation. The technological interfaces for all of the activities were modified to give students the option of submitting information to the class display space with or without their names attached. All submitted digital artifacts, across all four activities, were collected and analyzed to evaluate the frequency with which students chose to attach their names to their input. At the end of each activity student were given a questionnaire regarding their use of anonymity in the day's lesson. Finally, at the completion of the four activities, video taped interviews were conducted with the students.

Findings

Statistical analysis of the digital artifacts submitted by the students during each activity revealed no significant differences for use of names by activity or gender. A generalized linear model for repeated sample data was done for each question on the questionnaire. Analysis showed, with statistical significance, that students perceived the activities to be different. Qualitative analysis of the open response portions of the questionnaire revealed that for less generative activities, students' comments about the attachment of names revolved around confidence in the correctness of their answers. As activities became more generative, the quality of comments changed to revolve around strategy and aesthetics. The video interview were transcribed and analyzed qualitatively to identify themes in comments. By far the most common theme in the statements made by students, dealt with anonymity being important for risk mitigation (avoid embarrassment, lack of confidence, etc.). Finally, all three forms of data were compared. An incongruity between statements and actions emerged from this comparison. Females more frequently made comments about wanting to be confident of their answers before they would attach their names. Males much more frequently expressed that anonymity was not important to them. Yet the use of names by the two groups across activities was virtually identical at approximately 60%.

Before a comparison of activities was meaningful, it needed to be determined if the students perceived the activities themselves as different. Questionnaire data showed that students interpreted the activities to be different. Contrary to expectations, there were no significant differences in student use of anonymity across the four activities. Students tendency to reveal their names fluctuated by only 11 percentage points (57% to 68%) across the activities. Students' open ended responses on the questionnaires showed that they perceived the utility of anonymity to differ across the four activity types. For the Questioning and SimCalc activity, a major theme in students' reported reasons for utilization of anonymity was confidence in the correctness of their answer. Both of these activities had the possibility of wrong answers. The two activity types differed greatly in the numbers of possible solutions available to the students, still incorrect answers were possible. In response to their participation in the Disease activity, students refer to using anonymity for strategic reasons. The Disease activity, where there was no possibility for incorrect participation (even if a student did not move his/her icon they were still a valid participant in the activity), was the first time that confidence in correctness of response no longer appeared as a theme. Finally, in the Regression activity comments of aesthetics emerged. Students' concern for showing their name became about not "cluttering" the screen. This variation of concern changing from right answers, to strategy, to aesthetics indicates a difference of utility of anonymity.

Conclusions

Tying the remarks made about confidence in answer, from the questionnaires, to comments about risk mitigation, from the interviews, anonymity being used to avoid negative consequences was by far the most important feature for the students. Students' perception of the potential, in an activity, for their responses to be right or wrong, was what most clearly delineated differences in activities. Concepts of right and wrong input were the students' way of interpreting differences in levels of generativity. The interaction between Generative Activity design and anonymity was demonstrated by the change in content of the student comments on the utility of anonymity. In the more generative simulation environments, students' ideas about their utilization of anonymity turned from subtractive (risk management) to additive (strategy and aesthetics).

In addition to students' perceptions of anonymity, analysis of classroom videotape showed that when a response was in the display space with no name attached, if the teacher initiated a discussion of the response, the conversation was left open to the whole class. Questions like, "What might this person have been thinking?", were asked. In contrast, if the response the teacher wanted discussed had been submitted with a name attached, he would turn to that specific student and ask them to explain their answer. For this reason, the display of names could be said to reduce student agency. The ability for anyone in the classroom to take ownership of any response in the display space disappeared.

It is important to note that this project was not seeking to identify those situations in which anonymity should no longer be used. The author holds a very strong belief that anonymity is a critical feature of next-generation classroom networks and 40% use of anonymity is a sizable fraction of the students. If, during class discussions, students want to take public ownership of their answers, that is their choice, and that choice should not be taken away. The goal of this study was to better understand anonymity and, oddly, that was best accomplished by exploring its removal.

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Computer Supported Moderation of E-Discussions: the ARGUNAUT Approach

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Abstract: Despite their potential value for learning purposes, e-discussions do not necessarily lead to desirable results, even when moderated. The study of the moderator's role, especially in synchronous, graphical e-discussions, and the development of appropriate tools to assist moderators are the objectives of the ARGUNAUT project. This project aims at unifying awareness and feedback mechanisms in e-discussion environments, presently implemented on two existing platforms. This system is primarily directed to a human moderator and facilitating moderation, but might also help the students monitor their own interactions. At the heart of system are the inter-relations between an off-line AI analysis mechanism and an on-line monitoring module. This is done through a collaboration of technological and pedagogical teams, showing promising preliminary results.

Introduction

One of the important trends in Computer-Supported Collaborative Learning/Working (CSCL/W) is the proliferation of tools to support e-discussion so as to reach learning objectives. Discussions, however, do not necessarily lead to desirable results but often turn out to be ineffective or chaotic when no moderator/tutor is present. The ARGUNAUT project's (IST-2005027728 - Partially funded by the EC under the 6th Framework Program, http://www.argunaut.org) goal is to provide moderators with a computerized tool to support and increase their effectiveness and thereby the quality of the monitored e-discussions. ARGUNAUT aims at delivering a unified mechanism of awareness and feedback to support moderators in multiple e-discussion environments. The tools that are being developed within the project not only help the moderator visualize information about relevant aspects of the discussions taking place ("awareness"), but also pinpoint possible problematic issues, give "advice" to the moderator in real time, and support his/her intervention. In addition, the tools provide the moderator with options for post-discussion reflection and awareness. ARGUNUT supports two existing collaborative learning environments; Digalo (developed on the DUNES project – IST-2001-34153 - http://www.dunes.gr/), and Cool Modes (http://www.UDE.info/).

Since feedback and advice to the moderator regarding the current e-discussion are among the main goals of ARGUNAUT, a primary need was to define criteria for the quality of discussions. Observations of the argumentative practices that developed in classes led to the elaboration of criteria such as participation, responsiveness, and Toulminian criteria for the quality of the arguments (see also Schwarz & Glassner, in press). Walton (1989) types of dialogue and Baker's approach (2003) to the use of argumentation in online dialogue helped us to elaborate criteria for quality. Since the criteria are about dialogical models of reason, at least two levels of analysis were required: an account of intersubjective orientations and an account of ground rules fulfilled during interaction (see Wegerif & Mercer 1997 for the description of ground rules in classroom dialogues). Such criteria inspired us to come up with analysis schemes for e-discussions in the ARGUNAUT context. We present here the ARGUNAUT system, developed in the hope that it will contribute to the moderators in their goal of facilitating good quality e-discussions.

The ARGUNAUT Approach

During the conference, we plan to present the ARGUNAUT approach of supporting moderation, as well as the initial prototype (partial functionality) of the ARGUNAUT system. Various features that have been developed so far will be demonstrated in the context of the pedagogical scenarios.

ARGUNAUT Scenario, Main Components and Architecture

The ARGUNAUT platform incorporates two modules, the "deep loop" and the "shallow loop". The "*shallow loop*" is a module for monitoring ongoing discussion. This module collects data about awareness variables or "indicators" (e.g., participation, social interaction). If a possibly problematic or significant situation (pre-defined as such) is detected, a dialogue appears, giving the moderator the relevant information, plus advice and "remote control" intervention options when applicable. The "*deep loop*" is an off-line analysis mechanism based on machine-learning techniques. This module takes human-annotated examples of past e-discussions (situations, or aspects thereof) and attempts to learn the examples' underlying pattern, or classifiers. These classifiers can then be used to detect similar situations in future discussions. A schematic overview of the architecture is shown in Figure 1.

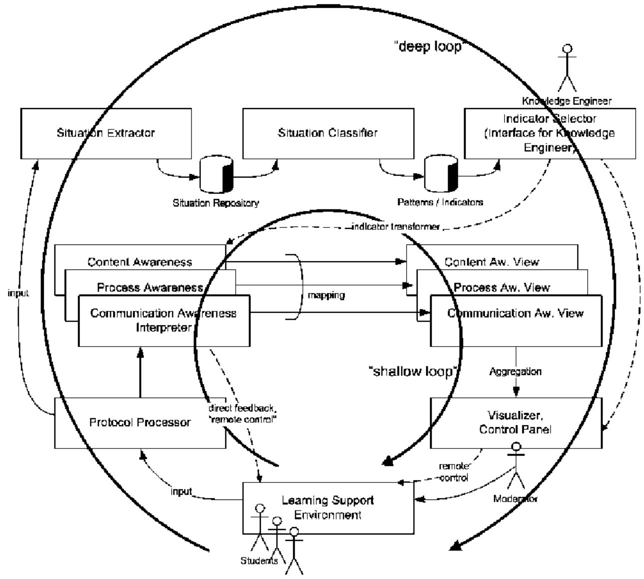

Figure 1. Planned System Architecture

The 'Indicators for Deep and Shallow Loop Classification' Approach

The offline analysis module – the deep loop- is designed to derive situation indicators. The underlying approach used by the deep loop is classification learning, i.e. induction of classifiers from labeled examples, which can later be used to classify new and previously unseen examples. According to this approach, (a) our experts and researchers pre-define a typology for classification according to specific concepts (e.g., 'critical reasoning', a central concept for e-discussions in education); (b) discussions then are annotated according to these typologies or schemes, and these annotations are analyzed offline; (c) the output of the offline analysis is a set of situation classifiers, which may then be incorporated as indicators into the visualization and awareness components of ARGUNAUT. These modules are planned to also enable induction of relations between the indicators and generation of feedback for the moderator (and the learners), explaining the situation and offering advice. These possibilities will rely on "post-processing" of indicators produced automatically by the system, and increase the usefulness of the indicators for participants in the electronic discussions.

The on-the-fly analysis and visualization module – the "shallow loop"- provides methods that are "lighter" with respect to computability and complexity and thus can be utilized on-the-fly. These methods provide the moderator with awareness feedback: information about specific characteristics of the monitored e-discussions. This information can be categorized into three types of awareness: a) *process awareness*: related to temporal traits of the discussion, such as phases, key events; b) *content awareness*: content-related properties, such as foci of interest within the discussion, relations between contributions, etc.); and c) *communication/social awareness*: related to the social interrelations between the participants of a discussion, such as typical patterns of interaction between specific participants. Each time an "interpreter" component produces new information based on activities within the learning support system(s), the data is sent to the corresponding view(s) and integrated into the user interface that is available for the moderator, using elaborated visualization features.

The shallow and deep loops together enhance the capabilities of the moderator by explicitly marking situations of interest. The moderator may also further annotate discussions on the fly (or after the discussion), relying (among other things, on the indicators produced by the offline analysis. The moderator's annotations may in turn be used for further refinement of these indicators.

Steps towards Implementation: First Results

Cross-System Interoperability and the Moderator's Interface

The ARGUNAUT system is designed to achieve interoperability, that is to say, serve more than one e-discussion end user environment (EUE). Since actions, objects and users are logged differently across e-discussion tools, there was a need for a "common format", a unified representation schema for action logs from both EUEs handled by the project. This was achieved via the use of transformational approaches converting the action logging of the EUEs to common format XML logs. The ARGUNAUT 'Moderator's Interface' includes a unified graphical representation and a cross-system replay system based on this common format, which allows the moderators to monitor the discussion in progress, regardless of the concrete EUE the students are using. It also includes the ability to make content keyword queries, annotate discussions, and intervene in the students' EUEs via remote control capabilities (see Figure 2).

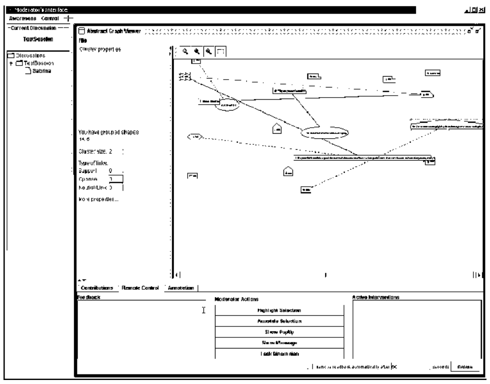

Figure 2. ARGUNAUT's Moderator Interface

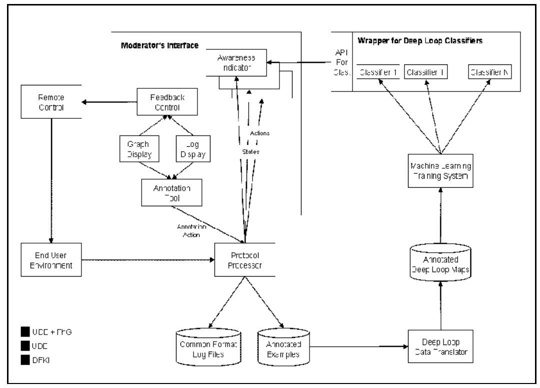

Figure 3. The Integration of the Deep and Shallow Loops

Offline Analysis and Annotation of E-Discussions

At this stage, we have not determined absolute criteria for quality of e-discussions. Rather, we have focused on identifying and annotating phenomena relevant to the analysis and evaluation of such discussions. Our initial experiences would suggest that actions, objects and attributes in the discussion log files, can be successfully used to capture these more meaningful theoretical phenomena. This can be achieved by the combination of structural and process-oriented elements (e.g., ontologies of shapes, types of connectors, logged actions) with content elements (the text of the discussion itself). One direction for this is the training of machine-learning classifiers to classify discussion units (shapes and paired-shapes) into pre-defined theoretical categories, using structural and process-oriented attributes. The classifiers are trained with examples categorized by humans, based on content and some contextual cues. At this point we already have a few classifiers for phenomena such as 'critical reasoning' and 'question and answer', showing high overall accuracy (86-95%). A second direction is the use of a PROLOG-based pattern matching tool (Harrer, Vetter, Thür, & Brauckmann, 2005) in conjunction with e-discussion XML log files to generate "rules" in order to look for "patterns" that combine user actions (e.g., create shape, delete link) and structural elements with content key words.

Integration of Deep Loop Classifiers with the Online Shallow Loop

As described above, the AI module of ARGUNAUT (the "deep loop") has been successful in generating some classifiers. We are now in advanced stages of integrating these classifiers with the online monitoring module (the "shallow loop"), as shown in Figure 3.

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Fostering Audience Design of Computer-Mediated Knowledge Communication by Knowledge Mirroring

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Abstract. Higher education is increasingly realized by net-based scenarios often incorporating collaborative activities. This is accompanied with specific benefits but also constraints. In computer-mediated peer-tutoring for example it is more difficult to construct mutual models, thus impairing collaborators´ grounding, audience design and coordination. In this paper `Knowledge Mirroring`, that is providing information about the partner's knowledge, is introduced as technological support developed to compensate for these problems. Effects of Knowledge Mirroring on audience design and knowledge acquisition are studied in a simulated peer-tutoring scenario with explaining as basic activity. Analysis of explanations revealed audience design with respect to usage of elaborations and references. Results regarding knowledge acquisition show that learners provided with Knowledge Mirroring were able to draw more inferences on information distributed across the learning material.

Computer-mediated knowledge communication

Higher education is increasingly realized by net-based collaborative scenarios. Thus, by analysing the specific constraints of computer-mediated collaborative learning effective support can be developed. *Knowledge Mirroring* (KM) follows recent interest in *group awareness tools* (Soller, Martinez, Jermann, & Muehlenbrock, 2005). As KM provides learners with relevant information without explicit instruction on how to use the information it is classified as implicit learner support. The effects of KM on communication are investigated in an experimental study. Among the various tasks that can be implemented within collaborative learning this study focuses on two basic activities within peer-tutoring: question-asking and explanation-giving.

For peer-tutoring to be effective learners need to construct adequate models of their partner's knowledge (Chi, Siler, & Jeong, 2004). However, initial models are biased towards the model of one's own knowledge (Nickerson, 1999). Even worse, common strategies of verifying models are frequently ineffective (Person, Graesser, Magliano, & Kreuz, 1994). In addition to these problems also arising in face-to-face tutoring, particular affordances and constraints are being introduced when peer-tutoring is realized through computer-mediated communication (e.g. mail, chat). More specifically, costs of grounding vary with the medium (Clark & Brennan, 1991). Altogether, in computer-mediated peer-tutoring it is more difficult to construct mutual models, establish common ground and adapt utterances to the specific partner, i.e. perform audience design (Clark & Murphy, 1982). KM is introduced in this paper as a method to compensate for these specific problems by providing information about the partner's knowledge. This is assumed to improve *adaptation of communication* and knowledge acquisition. KM offers information on which to adapt utterances for more efficient communication (Grice, 1979). Support for *knowledge acquisition* is suggested as audience design of explanations elicits additional elaboration and re-organisation of knowledge. Giving as well as receiving elaborated explanations was shown to enhance learning (Webb & Palincsar, 1996).

Research method

The primary goal of this study was to facilitate audience design in peer-tutoring by providing KM. As the focus was on production rather than reception of explanations a simulated peer-scenario was chosen. Thus, participants were not interacting directly with a learning partner but formulated explanations for a simulated partner in asynchronous communication.

Design. 42 participants were randomly assigned to two conditions (with versus without KM). Subjective estimations of understanding were assessed. In the control condition (CC) only Ss´ own knowledge was presented in the KM-Tool as knowledge (see green tags in Figure 1) or deficit (not tagged). Ss in the experimental condition (EC) were additionally provided with the knowledge of a simulated partner. The partner's knowledge was computed systematically relative to the participants´ knowledge resulting in three types of combinations: shared knowledge (both tagged), shared deficit (neither tagged), complementary knowledge (only participant tagged).

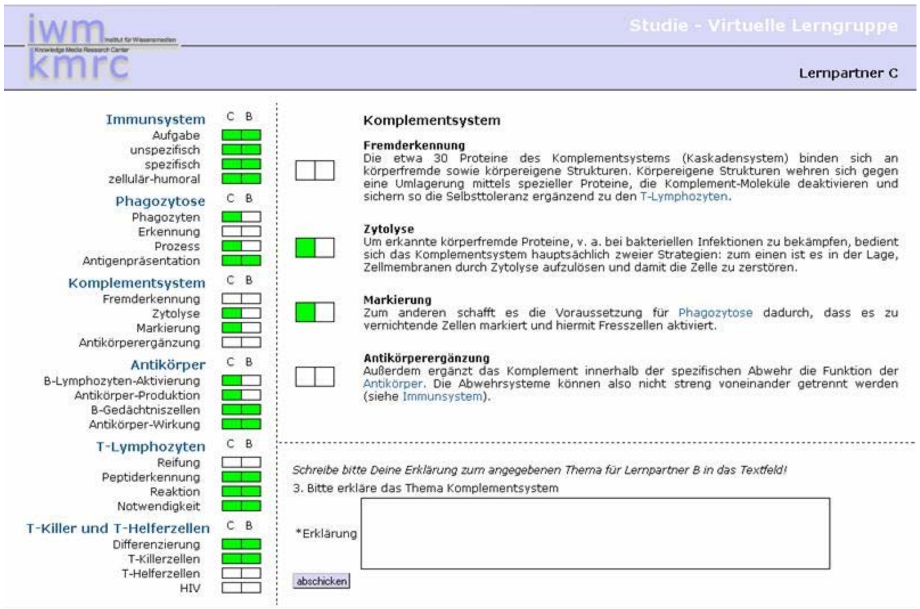

Figure 1. Explanation-giving task within EC. On the left side KM is realized by two columns next to the topic list. The left column displays participants´ knowledge and the right knowledge of the simulated partner. Only the left column is displayed in CC. On the right upper part learning material is presented along with KM-information for the respective topic. In the right lower part a field is available for formulating explanations.

Procedure and Analysis. First, participants learned individually for 25 minutes with a hypertext providing information on the immune system. For the following 25 minutes they wrote explanations for a partner on four pre-selected topics. KM was available during the explanation task in the EC. KM was assumed to induce audience design and thereby activities beneficial for learning. Audience design was assessed by analysis of formulated explanations, whereas learning outcome was measured after the explanation task by a 48 items multiple-choice test capturing factual (24 items) as well as local (information on one page of hypertext) and distant (information distributed over pages of hypertext) inferential knowledge (12 items each).

Results

Audience Design

Explanations were coded for the following indicators of Audience Design: number of words, elaborations, and references. An elaboration was assigned if the explanation provided additional information (e.g. from prior knowledge) that was not contained in the learning material. References were assigned when other parts of the learning material were used as a basis for the current explanation.

Audience Design (i.e. adaptation to the partner's knowledge) was assumed to result in different mean numbers of words, elaborations, and references (see Table 1) between tagging combinations in the EG. A within-subject ANOVA revealed significant differences between tagging conditions for number of words ($F(2,11) = 4.4$, $p < .05$), and references ($F(2,14) = 5.1$, $p < .05$), but not for number of elaborations ($F(2,14) = 0.8$, $p = .48$). T-tests for paired samples revealed significantly more words for complementary knowledge than shared knowledge ($t(17) = 3.6$, $p < .01$) and shared deficits ($t(12) = 2.4$, $p < .05$) as well as more references to shared knowledge than to complementary knowledge ($t(20) = 3.5$, $p < .01$) and shared deficit ($t(20) = 2.7$, $p < .05$).

Knowledge acquisition

An ANOVA performed on achievement in the knowledge test revealed a significant effect of condition only for distant inferential knowledge (53% vs. 41%; $F(1,40) = 4.4$, $p < .05$). In the remaining subtests a consistent but non-significant better performance of EC was found. Correlative analyses showed that performance in the distant inferential test was moderately associated with absolute (i.e. number of elaborations and references) but not with relative audience design indicators (e.g. ratio of references per type of tagging combination). However, according to additional regression analyses neither of the absolute indicators mediates the effect of experimental condition on performance in the distant inferential knowledge test.

Table 1: Indicators of Audience Design for each tagging combination in the experimental condition.

	Mean number of words	Mean number of elaborations	Mean number of references
EC: shared knowledge	11,7	0,10	0,67
EC: complementary knowledge	16,9	0,29	0,05
EC: shared deficit	10,4	0,24	0,19

Theoretical and educational significance

Enhancing efficiency and effectiveness of computer-mediated knowledge communication is the main purpose of this research project. Evidence of support for audience design and knowledge acquisition by KM during explanation-giving is presented. As a next step it will be investigated whether recipients benefit from audience-designed utterances. KM is flexibly and easily applicable to a multitude of collaborative learning settings and domains (e.g. physics), particular value in complex learning domains of higher education is supposed.

Recently, a multitude of tools providing awareness of group characteristics was developed (Soller et al., 2005). Empirical validation of awareness tools can be found e.g. in research on expert-layperson-communication (Nückles, Wittwer, & Renkl, 2005). This study complements this body of research by investigating processes triggered by awareness tools within a peer-tutoring scenario.

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A Reflective Analysis of Facilitation in an Online Problem-Based Learning Activity

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Abstract: The first author collaborated with the second to analyze his facilitation of online problem-based learning (PBL). A framework for analyzing reflective collaboration in science instruction developed by Radinsky (2000) was adapted to examine threaded discourse in an online teacher education course. In the spirit of Schön (1983), we proffer this method as a tool for analyzing and improving one's online facilitation of PBL and for developing scientific hypotheses about connections between facilitation and learning.

Introduction

We present a method for evaluating discourse in online problem-based learning (PBL) groups while simultaneously helping new online facilitators (usually graduate students) reflect on how their facilitation affects that discourse. We illustrate the method using data collected during a problem-based learning (PBL) activity implemented entirely online as part of a learning-sciences course for pre-service teachers. PBL is a form of instruction in which learners collaboratively engage in ecologically valid problems with the goal of promoting transfer of knowledge to professional practice (Barrows, 1988; Koschmann et al., 1994;). PBL is a student-centered form of instruction that replaces the teacher with multiple small-group facilitators (Dolmans & Schmidt, 2000; Meyers Kelson & Distlehorst, 2000). The facilitator operates as a guide who pushes students to think deeply and work effectively (Dolmans & Schmidt, 2000; Hmelo & Lin, 2000; Koschmann, Glenn, & Conlee, 2000). During the online PBL activity in the present study, one of the authors ("MD") served as the facilitator. Following the activity, we employed a method for analyzing patterns in collaborative discourse, based on a framework by Radinsky et al. (2000), to create explicit graphical representations of group interaction. These representations became objects for supporting analysis of facilitation strategies, which took place in post-course reflection sessions. In the spirit of Schön (1983), we claim that this method for supporting structured reflection is not just a tool for analyzing and improving one's teaching, but also a methodology for developing scientific hypotheses about connections between small-group facilitation and learning.

In online PBL, the role of the facilitator is complex and multifaceted. He or she is responsible for monitoring student and group process as well as the progress and understanding of individuals. Unlike a typical classroom setting in which the teacher does 95 percent of the questioning and tends to focus on short-answer questions (Dillion, 1990; Graesser & Person, 1994), PBL aims to be much more student-centered. Fostering reflective, constructive discourse wherein much of the questioning is done by the students is a major goal of PBL. To accomplish this, the facilitator tends to ask a variety of complex questions that focus students not only on the domain and problem but also on group processes while at the same time scaffolding students to assume responsibility for self-directed collaborative learning (Hmelo, 1998; Hmelo & Lin, 2000; Persons & Graesser, 1999). Looking at face-to-face PBL instruction, Hmelo-Silver (2003) studied Howard Barrows, the acknowledged founder of PBL and a well-known facilitator, to gain a better understanding expert facilitation. The nature of expert PBL facilitation was not easily captured: it is a complex and often subtle form of practice. Not surprisingly, it can be an extremely challenging pedagogy for new facilitators to master in face-to-face situations (Derry et al., 2004). Although asynchronous tools within online PBL environments my slow the speed of interaction, decreasing facilitators' cognitive load and allowing more time for reflection during facilitation, the online environment nevertheless adds an additional aspect of unfamiliarity and, as this study will illustrate, challenges for those learning to facilitate PBL on line.

The Context

The present study utilized data collected from an online course for preservice teachers focusing on the learning sciences, particularly cognitive and sociocultural theories of learning and instruction. A goal of the course was to promote students' abilities to *use* learning-science concepts and theories to both analyze and design classroom instruction. A web-based environment was developed to support this course (Derry et al., 2005) and consists of three sets of tools: (1) an online PBL activity center in which students can engage in collaborative problem solving and discussion using a structured whiteboard and threaded discussion board; (2) an online hypertext book called the Knowledge Web, a collection of interconnected web pages dealing with learning-science concepts that students in the course use to conduct independent research; and (3) an online video library containing video cases of classroom instruction with links to relevant learning-science concepts in the Knowledge Web. Facilitators interact with students through a web interface that gives them access to all student work and activity.

Table 1 Collaborative steps of the PBL activity

Step	Tasks Involved	Step Goals
3	Join group.	Become familiar with group members, nominate minicases.
4	Select clips from video case to analyze; select concepts to utilize in analysis.	Narrow the scope of the analysis to a manageable piece of video (2 minicases) and reasonable number of concepts (3 Concepts).
5	Research concepts selected for analysis.	Become more knowledgeable about concepts chosen for the analysis.
6	Analyze the selected video segments using researched understanding.	Collaboratively investigate how the chosen learning-science concepts may be applied to the chosen minicases.
7	Construct the final analysis.	Synthesize group's research and discussion to produce an analysis of how the chosen learning-science concepts apply to the video case.

The PBL activity implemented for this study consisted of 12 steps, which, for research purposes, could be divided into two phases. The first phase of the activity (steps 1-8) required students to both individually and collaboratively analyze a video case of instruction, taking a learning-sciences perspective. The second phase of the activity (steps 9-12) required students to individually design lesson plans and justify them with learning-science concepts. It was intended that the video analysis portion of the activity in phase 1 would provide students with a rich understanding of a set of learning-science concepts they could use to help design their instruction in phase 2. Steps 3 through 7, described in Table 1 above, are the focus of the present study as they are where MD interacted with students and facilitated collaborative group activity on line. Students worked mostly individually on the activities that came before and after steps 3 through 7.

Methodology

Data Source

Two groups of five students worked with MD over a period of several weeks. MD was a teaching assistant who had some training and a little experience facilitating PBL in face-to-face settings, but he had not worked on line. The students were advanced undergraduate pre-service teachers majoring in secondary education and one in-service graduate-level teacher. The activity occurred completely online; students did not attend regular class meetings for the duration of the activity. The data for our analysis were collected from the threaded discussion board embedded within the instructional environment. This discussion board was the primary tool for communication. While email was also used as a method of communication, it was primarily a one-way channel that MD utilized to occasionally disseminate course announcements. The discourse that emerged on the discussion board provided a window into students' thinking and also into MD's facilitation and its influence on student thinking.

Analytical Framework

We adapted a framework for analyzing group discourse developed by Radinsky et al. (Radinsky, 2000; Radinsky, Liemberer & Gomez, 2000). Radinsky et al. aligned their model with the pedagogical theory of Dewey (1933) noting "Dewey placed reflection at the center of his model of teaching and learning, as a key piece of the process of making sense of experience" (p.9). In this framework reflection is defined as *purposeful thought or activity directed at making sense of "situations … containing a difficulty or perplexity"* (Dewey, 1933; quoted in Radinsky et al., 2000, p. 9). Reflectiveness is not seen as a momentary phenomenon, but rather as a dispositional and enduring characteristic of individuals that develops within activity systems.

Radinsky et al. developed their framework in the context of a middle school science classroom in which students collaboratively engaged in analysis of complex sets of geological data. In analyzing the data, students applied the conceptual knowledge of the domain to develop physical models (e.g., miniature tectonic plates) that explained patterns in the data. While this context is obviously different from the context of the present study, there were important similarities that justify our borrowing of their framework. First, the activities that Radinsky et al. analyzed were collaborative in nature; students engaged in complex problems and discussed their thinking during the activity. Second, the activity that Radinsky et al. studied required students to model complex data sets to learn course content. Similarly, the students in our study engaged in collaborative analysis of a video case of instruction using conceptual perspectives based on The Learning Sciences to explain and model cases. These video cases are essentially complex data sets that, within our course, must be parsed and modeled and interpreted using theoretical and conceptual lenses. This requires students to exert effort to make meaning and is essentially a reflective task.

Table 2 Components of Radinsky et al. (2000) analytical framework

Context	*Component*	*Description (Operational adaptations developed for this study)*
Data	Data Items	Reflection on specific items within the video data set.
	Data Patterns	Reflection on broader slices of video, described with broad characterizations; particular events are not mentioned.
	Real World Items	Reflection on real life examples from outside the data corpus.
	Domain Concepts	Reflection with concepts from learning-science curriculum of the course.
	Conceptual Models	Domain concepts are used to explain and analyze segments of the video and advance instructional design principles as causal models.
Task	Action Decisions	Reflection on how to proceed with the activity.
	Characterization of the Task	Reflection on general purpose or goal of task.
	Teacher Guidance	Reflection on the contributions and guidance provided by the facilitator.
	Artifacts and Tools	Reflection on what and how artifacts and tools are to be used in the activity.
	Group Norms	Reflection on how the group interacts to complete the activity.
Role	Student Identity	Discussion of or reflection on personal identity.
	Beliefs/Understandings	Reflection on current understanding or beliefs related to task.
	Prior Experience	Reflection incorporating prior experiences related to the task.
	Conception of Norms	Reflection on how individuals are to participate both socially and intellectually in the activity.
	Student Roles	Personal reflections on how one should participate.

Radinsky (2000; Radinsky et al., 2000) claimed there were three contexts in which reflection occurred during an instructional activity: data, task, and role. They described each as follows:

> The ‘data context’ is a representation of what we want students to think about and figure out: domain concepts, sets of data for them to study, the real-world items which data represent, and models representing all of these things. The 'task context' is a system of activity in which we hope this mode of thinking will develop, through instruction. The ‘role’ context is a system of individual factors which contribute to a student’s mode of participation in inquiry and other kinds of classroom activity. (p. 17)

Within each context were five components or topics for reflection, which are listed on the left side of Table 2.

Radinsky looked for changes in student reflection patterns across the three contexts over time, watching for a maturing of their “reflective dispositions for investigating complex data.” Within the context of our course focusing on collaboration, transfer and use of learning-science concepts in teaching practice, maturing patterns of reflection might include evidence of students' developing interest in self-directed learning about the subject, taking responsibility for their collaboration, or increasingly connecting the conceptual analyses required by their instructional activities to their real-world classroom experiences (they were simultaneously enrolled in a practicum). These dispositions would be manifested in our analyses as students' increasingly reflecting on particular elements within the data, task and role contexts in ways that suggest owning the task and connecting it to their lives.

Coding

To enable us to code our data using this framework, Radinsky's components were adapted and operationalized to fit our instructional context (see the right side of Table 2). Each component in Table 2 was considered a potential subject for student reflection. Online posts were coded to identify which subjects of reflection occurred. Below is an example in which a student's post contained a reflection on instructional guidance and a learning-science domain concept (modeling) after getting advice from MD about how to proceed with the activity. (In the example below teacher education students are viewing a video of a high school social studies class in which secondary students in the video are themselves engaging in PBL and in which the teacher in the video is modeling self-directed learning behaviors.)

> **[Student]:** As [MD] mentioned, PBL is new to this group of students (Code: INSTRUCTIONAL GUIDANCE) and I think that is key for recognizing the modeling (Code: DOMAIN CONCEPT) in this situation.

All data from the online posts during steps 3-7 of the online activity were coded. Coding reliability was calculated to be 85% (percentage of exact agreement) using two coders looking at 20% of the data. After coding, each discussion thread was analyzed in a process that involved mapping it onto a graphical representation of the Radinsky et al. framework (see Figure 1 below). The term "thread" refers to a series of posts that resulted from responses to a single post initiating a topic, which was usually done by the facilitator. Each line (labeled with participant initials and numbers representing order of post) in the map represented a student or facilitator post. The nodes connected by each line represent the components within the three contexts of reflection that a particular post addresses. Threads, which represented distinct phases within the activity, were analyzed with separate graphical representations.

Results

The collaborative video analysis activity was designed to have five online steps (steps 3-7, see Table 1). In step 3 the group logged on to the threaded discussion board for the first time to introduce themselves and nominate minicases (short segments within the video) to focus on for their analysis. In the fourth step of the activity, students were to reach consensus on two video segments ("minicases") to focus on as a group and on what "learning issues" (in PBL parlance), that is, what learning-science concepts, they wanted to further investigate in depth for use in their video analyses. In steps 5 and 6 they conducted individual research into learning-science concepts and brought their research back to online discussions of the minicases, sharing their knowledge in the process of collaborative analysis. Step seven was a deadline for submitting the final written analyses of the selected video minicases. In practice, the facilitated discussion threads did not follow these steps exactly; the groups and facilitator sometimes collapsed or altered the sequence slightly as required. The analysis reflected actual structure of the discussion as it unfolded rather than the precise structure of the activity.

In the following we report illustrative analyses for one group, illuminated by three "Radinsky Maps" and MD's reflections. The maps were selected to reveal trends in early, middle and late stages of the activity, offering a picture of how the collaboration evolved. The reflections offer explanations that connect facilitation decisions to the trajectory of the collaboration.

Three Radinsky Maps

Introductions and Minicase Nomination Thread.

MD began a thread on the discussion board with a post asking students to introduce themselves and to nominate two minicases for the group to analyze. Students responded by providing what they were asked for, introductions and minicase nominations. For example, one student posted:

> **[CK]:** Hi everyone!! My name is ***, or ***, it doesn't really matter to me. Let's see, something interesting about me...I played tuba for four years in the UW Marching Band and marched at the Rose Bowl twice. I have already graduated once from the UW, with a double major in Animal Science and Ag Journalism. So, needless to say, it seems like I've been in school forever. Now, I am working on my dual certification in biology and agriscience. This summer I will be taking a grad class taught by my advisor in Australia. I nominated minicase 4 and 6 for the discussion. Look forward to working with everyone this semester.

Other students posted similar introductions but adding further comments about minicases:

> **[JA]:** I really like case 8 because it shows what a student learned in participating in this activity. The student shows he knows two points on either side of the debate concerning school vouchers. I think that the case shows this student could reflect the results of the class. I like how it shows what the effort put into the activity produces

Introductions were slow coming in. Before they were complete MD pushed the group to move ahead and reach consensus on their minicases:

[MD]: Hi Everyone, To stay on schedule, we should move on to step 4 (choose which two minicases for the group to collaboratively analyze). I know that some of you haven't posted your introduction yet. Please post one if you haven't done so already. Basically what we need to do in this discussion is decide which two minicases are the most interesting and conceptually richest for discussion. Below I will summarize which minicases your group members nominated in their initial ideas assignment and their introductions. Let's use this as a starting point for discussion. What I need people to do is just jump in and start making arguments for why they think certain minicases should be the ones the group analyzes.

Please reply to this post with arguments for why certain minicases should be chosen. We need to choose these minicases fairly quickly to stay on schedule, so make sure you participate in this discussion.

The Radinsky Map for this segment looked as follows:

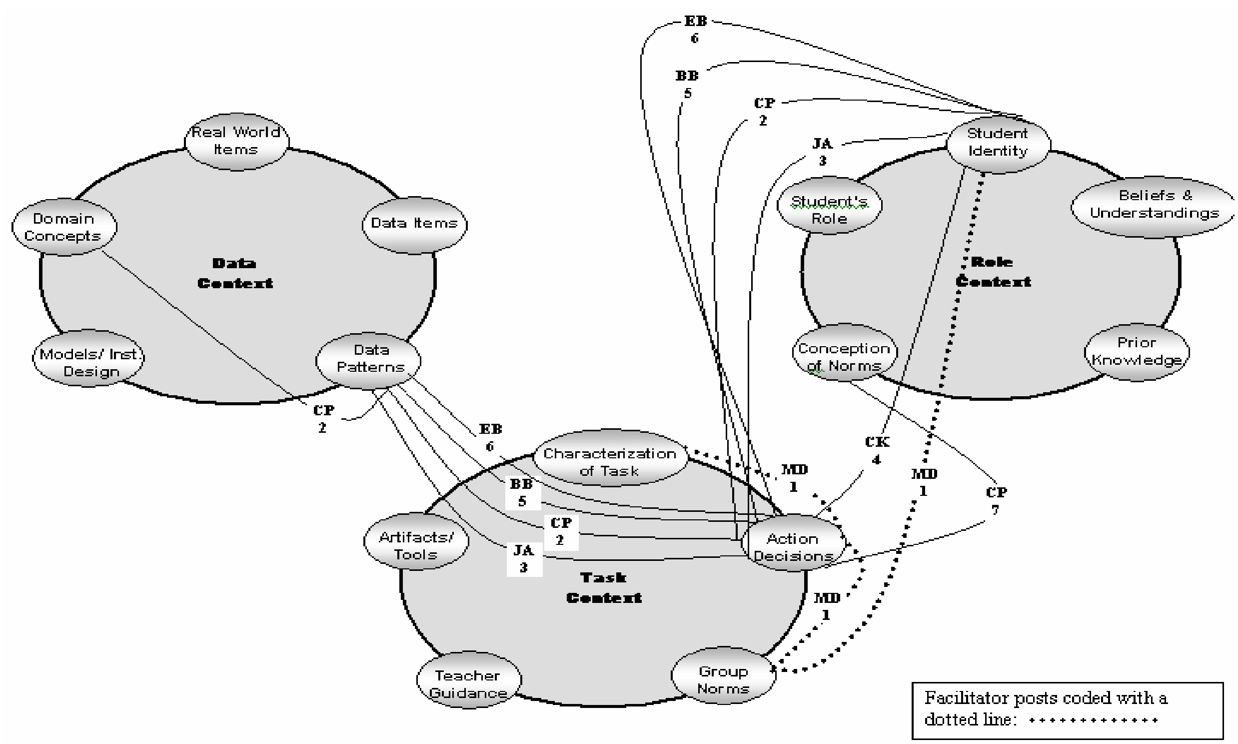

Figure 1. Analysis of Introductions/Selections Thread

As is shown in Figure 1, almost every post coded as reflection on student identity, action decisions (nominating a minicase), and data patterns (noting general characteristics of the minicases). Students nominated and gave reasons for particular minicases, but they did not debate which minicases were the best. Students made their indifference to this decision public:

[CP]: It may not seem like it, but it really doesn't matter to me which minicases we choose, as long as we get some deciding done and can get on with the whole process. This online discussion stuff is totally new to me and I'm hoping we can kick it into gear so we accomplish what we need to in a timely fashion.

CP's group members quickly echoed this post with similar sentiments.

MD Reflections on Introductions/Selection Thread.

Of the infinite ways a facilitator might introduce this activity MD chose this way for two reasons. First, the schedule was unforgiving. Second, this was the first time the students had worked in this online environment and with each other; some confusion and disorientation were expected. It thus seemed necessary to proceduralize the early part of the activity for efficiency, delaying more complex negotiations until later. So instead of problematizing this stage of the activity, to facilitate their entry he chose a proactive form of facilitation that tended to lead more than guide. In his journal MD wrote: "At this point, I envision myself being the person that blazes the path for others to follow. I want to create structure to this impersonal online environment." The students obliged by following MD's instructions.

One effect of this strategy appeared to be that students did not experience ownership of the problem. Nor did they experience a strong sense of “difficulty or perplexity” that might have promoted more reflection. At this stage of the problem there were several facets of the activity that could have been problematized by students. For example, the negotiation of the procedure for picking two minicases could have been subject to discussion. Later, at the time of MD's prompting of students to move ahead, it was becoming apparent that to stay on schedule the subtasks of the activity would need to be completed rapidly. While this post made clear that argument was expected, the criteria by which students were supposed to select and evaluate a minicase were left vague and subjective, although these too could have been problematized for negotiation.

MD's concern for the schedule and awareness that students needed logistical support may have contributed to a sparse and narrow reflection pattern. A reflective pattern in which students considered other issues such as group norms, participation norms, and characterizing the activity in a personally meaningful way might have occurred if there were a higher level of student ownership of the activity (Engle & Conant, 2002) and a sense of a compelling problem (Radinsky et al., 2000).

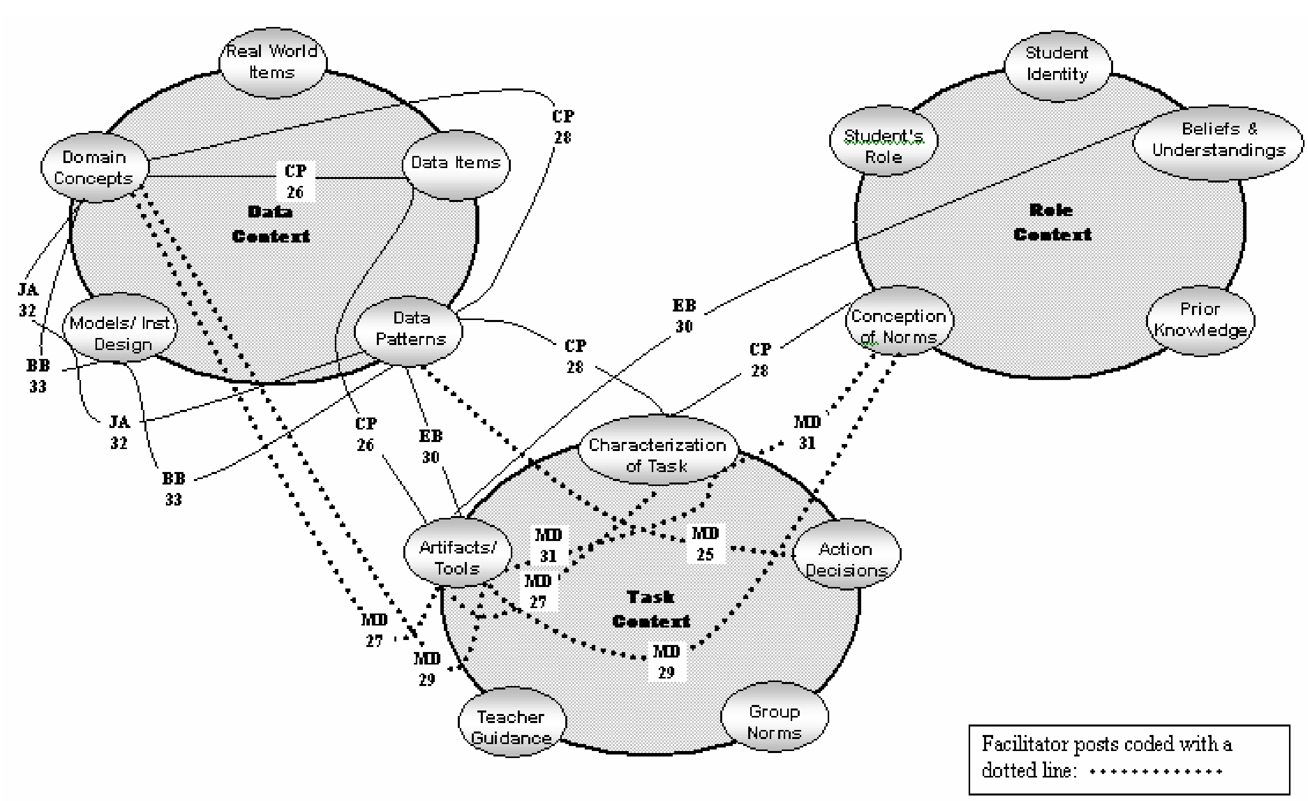

Figure 2. Concept Selection Thread

Concept Selection Thread (Step 4 Continued)

The task related to this thread was to select concepts that were likely to be keys to analyses of selected minicases and on which students would conduct research (the last of step 4 of the activity structure). Again, MD took the lead in beginning this thread with the following post asking students to share their ideas:

> **[MD]:** In this thread we will discuss what the relevant learning science concepts for minicase 8 are. In the previous discussion, some of you mentioned that this minicase shows what people learned from this lesson, what we might call learning outcomes. What other learning science concepts seem to be at play here?

As reflected in Figure 2, students are evolving their collaboration toward focus on the data context, specifically domain concepts, data patterns, and models, essentially sharing as individuals what potential learning-sciences concepts were "liked" or "seemed interesting" for analyzing chosen minicases. For example, JA posted:

> **[JA]:** In case 8 I like the concept of questioning. I think the way a teacher asks questions can make all the difference in a discussion and can make them elaborate when a two word reply would do otherwise. I think in the case you can see how the teachers questioning asks for both sides of the issue showing a neutral stance and just taking in all the research and again modeling appropriate behavior. So I think that the concepts I see for 8 are questioning and modeling.

MD Reflections on Concept Selection Thread.

Similar to MD's introductory post, this introductory post was essentially a short-answer question that requested information and gave no indication that this step should be problematized. A discourse pattern emerged in which students followed the facilitator's lead and did not display much agency in directing the activity or discourse. As is shown in Figure 2, the nexus of students' reflective discourse is in the process of moving into the data context. While there are posts that reference the task context, and to a lesser extent the role context, the majority of these were MD's. In these posts, MD characterized the task *for* the students and clarified how to use the tools. On these issues, students followed MD's lead. Moreover, they did not challenge or question one another's ideas, which might have fostered more reflection. This may be due to students interpreting the task set for them as one in which they find "interesting" ideas to research; hence it would make no sense to engage in controversy.

Collaborative Analysis: Research and Analyze (steps 5 and 6)

During steps five and six of the collaborative analysis, students began researching the concepts that they selected in the previous step of the activity and using them to analyze the minicases they selected. Figure 3 shows the graphical representation of one of the two threads in which students discussed their analyses. Each thread focused on one minicase analysis. Only one thread map is shown due to space limitations, but both maps are virtually identical.

As shown in Figure 3, students' reflective talk did make important connections among data patterns, domain concepts and instructional design models. An example from CK:

> **[CK]:** While there are many forms of assessment, Kyle chose a form of Authentic Assessment for measuring the progress of his students. Authentic Assessment is used when traditional methods are judged too narrow in determining the actual cognitive outcome. In this case Kyle used Performance Testing, or testing where students create a tangible product as a way to show their understanding of a subject matter. He also appeared to be assessing the students by asking them about the opinions they had developed. . . . Authentic Assessment . . . helps students develop a variety of skills instead of just the ability to regurgitate facts presented to them by the teacher.

To which MD responded:

> **[MD]:** I like the point that [CK] has made about authentic assessment. We were able to glimpse at the form of assessment that Kyle was using in this minicase. As [CK] points out, it seemed more authentic than a more objective assessment might seem. How might we use the concept of transfer to better understand this

assessment? What exactly might the "letter to the president" assessment be testing?

MD noted in his journal: "Because they are all doing their own research, they don't seem to be interested in questioning the research that others are doing."

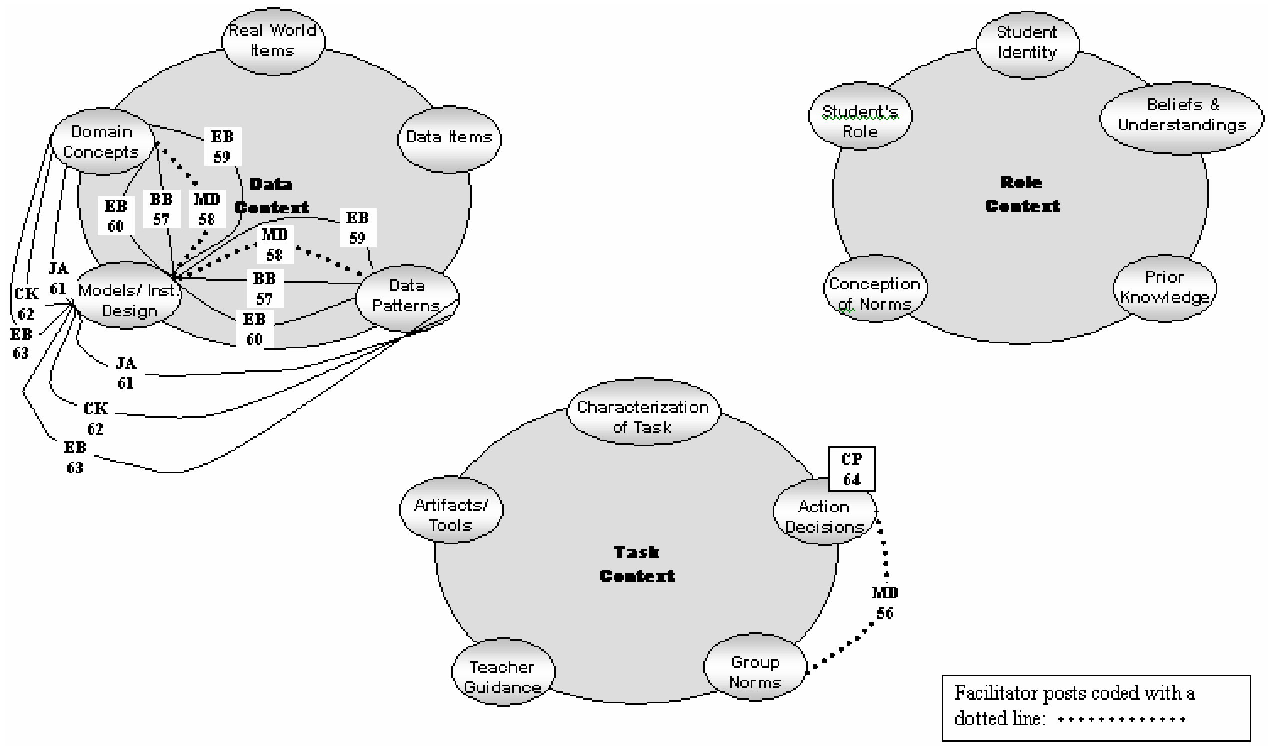

Figure 3. Conceptual Analysis Thread

MD Reflections on Conceptual Analysis Thread.

From the beginning MD had looked forward to steps 5 and 6 (the research and analyses steps) as having greater potential than earlier phases of the activity to support meaningful discussion. In these threads students did in fact begin to connect domain concepts and data patterns to build plausible complex models of instruction informed by learning-science concepts, which was an important instructional goal. This was viewed as a partial success for this phase of the activity. In addition, MD noted that his questioning strategies had evolved from primarily short-answer questions to long-answer questions. Nevertheless, *discussion* was not rich as students did not often challenge one another, which limited their need to reflect further on what they posted. Moreover, their evolved reflection patterns became even more narrowed and focused, failing to cover much range even within the data context: there were no connections at all to real-world or personal experiences, for example. Nor did they reflect on any components within other contexts of reflection (task and role). MD concluded that the pattern of explicit leadership he had demonstrated up to this point, along with the emphasized importance of sticking to the schedule and failure to set norms for problemitizing issues early in the task, likely hampered students from questioning one another.

Discussion

MD's strategy constrained students' involvement in the decision-making process early in the activity, which likely produced the narrow and relatively shallow reflection patterns that evolved in this study. In contrast to the patterns of questioning that Hmelo-Silver (2003) found an expert facilitator demonstrated, MD observed that his early questioning strategy employed mostly short-answer questions. Also missing from his repertoire were task-oriented questions that would push students to think beyond the domain content of the problem to question the nature of the problem and determine what process would be used to investigate it. However, multiple factors that seemed to be at play need to be considered and are discussed below.

First, the strategy that MD employed was successful on several levels. Students participated at persistent levels throughout the activity. Trial runs were performed on the system prior to this implementation revealing that (1) participation could not be taken for granted, it needed to be prompted; and (2) logistically complex activities can quickly result in confusion, lowering participation. In conquering these issues, MD used a strategy that essentially removed all logistical responsibilities from students early in the activity, in order to avoid the confusion and slowness that plagued trial runs of the system. As a result, in addition to participating and completing the activity, students were more focused on the content of the problem rather than logistics, as evidenced by their evolved reflection pattern within the data context in steps five and six. This created tradeoffs in that valuable aspects of the activity were sacrificed for the sake of getting it done. Such tradeoffs are ubiquitous in teaching (e.g., Leonard & Derry, 2006), but they are problematic.

The patterns uncovered in this analysis showed two things. First, students were highly focused on the paths that MD blazed for them: students closely followed instructions both in what they produced, but also in what they thought about, primarily domain concepts, data patterns, and models. Second, students did not reflect much within the task and role contexts proposed by Radinsky. This led us to question whether it is necessary to reflect on these contexts.

MD’s strategy of carrying the logistical load during the early activity was implicitly based upon his initial assumption that these logistics were not related to the intended learning goals. But this analysis confirms in our minds that this was a flawed assumption. Engle and Conant (2002) argued that in order for students to productively engage in a discipline, they need to be presented with intellectual problems in a manner that will provide them with the *authority* to frame and solve problems. Not ceding this aspect of the activity to students runs counter to strategies of successful facilitators (Frederiksen, 1999; Hmelo-Silver, 2003; Palincsar, 1999). The fact that students generally did not reflect on the task and role contexts suggests that students did not perceive themselves as owning the problem and hence they were not highly invested in or motivated by it. Students were not questioning or negotiating process or their own participation. Students did not argue (or care?) about what could serve as evidence that a particular learning-science concept was relevant or appropriate in a particular situation. And despite the course's focus on transfer, students never reflected on the relationship of their coursework to their teaching experiences or lives. It is possible to see this problem in another light as well: Researchers are recently writing about the importance of developing students' 21st century "soft skills" (e.g., Bereiter & Scardamalia, 2006). Such skills include communication, leadership and collaborative competencies that would likely be developed through reflective engagement in the task and role contexts.

The current study was a proof of concept that the Radinsky et al. framework can be generalized to an online instructional context in a very different domain and for a different purpose: supporting and organizing the reflective thinking of new online facilitators. For this we found the framework useful and reasonably efficient. The method had limits however. For example, it depicted the target and content of thought, but does not of itself reveal much about functional discourse strategies, which might be fostered through facilitation to promote greater reflectivity in groups. Moreover, we found ourselves questioning where reflectivity ended and 'plain thinking' began, and whether one statement was more or less reflective than the other. We resolved this temporarily with the assumption that public discourse in a PBL context is nearly always a form of reflection, although we are not satisfied with that answer.

It is also necessary to ask the extent to which the tools and technologies employed in the instruction imposed constraints on the instructional process, the facilitator, and students. MD's journal reflects numerous frustrations with limits of the technology, and we readily acknowledge that these exist. It is always likely that a better chat environment, interface, instructional design, or Internet service could make a big difference. It is possible that such technologies set a theoretical limit on performance that partially determines the effectiveness of PBL instruction. However, we sense that facilitators can make a huge difference in any environment, regardless of its design strengths and flaws. With this study we benefit from the learning and shared experiences of a brave facilitator.

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From socially-mediated to technology-mediated coordination: A study of design tensions using *Group Scribbles*

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Abstract. It is well known that scripts based on good practices can enhance the collaboration effectiveness and efficiency in CSCL environments. Yet, to achieve rich, interactive, and creative collaborative learning settings CSCL tools need new flexible, dynamic and lightweight metaphors. This design tension between social and technology-mediated coordination is difficult to resolve and worthy of close analysis. In this paper, we study such a tension through the use of the *Group Scribbles* (GS) CSCL tool, developed at SRI International, a GUI-based approach that enables the creation and enactment of lightweight CSCL scenarios. The potential of GS, as well as its limitations and possible extensions are studied in relation to design scripts based on Collaborative Learning Flow Patterns. Preliminary experiences in an authentic environment illustrate several facets of the design tension, such as the participants' workload and awareness, or the adaptation to emergent situations. On the other hand, this study points out the need for a new flexible architecture that complements *Group Scribbles*.

Introduction to the coordination design tension in CSCL scripts

CSCL, with its emphasis on both the disciplines of engineering and education, is about balancing competing forces, a familiar challenge to any emerging multi-disciplinary paradigm. On the one hand researchers advocate open, flexible, technology-mediated environments that support situated learning. On the other hand, student experiences are often measured against rigid learning goals. Furthermore, designers of a CSCL tool must often compromise their notions for an ideal learning environment in light of limited resources for designing, implementing, evaluating the tool. Thus, practitioners face the task of resolving many design tensions (Tatar, 2007) as they make decisions about appropriate technology and learning situations. These design tensions underlie and motivate design patterns in the field of technology-enhanced learning. While the CSCL literature is replete with descriptions of the final configurations of technology and learning situations, there is a paucity of reflective writing on how designers converged on their approach through an analysis of tradeoffs. The field needs more case studies of design to exemplify known tensions and identify new ones, so as to inform future CSCL projects. A particularly vexing design tension both in the field of CSCL and CSCW comes from the desire to use technology to structure group coordination, but at the same time support unanticipated, emergent coordinated activity.

> Design tensions conceptualize design not as problem solving, but as goal balancing. They draw explicit attention to conflicts in system design that cannot be solved, but only handled via compromise (Tatar, 2007, p. 3).

Based on this principle, a design tension helps us to identify relations between "what ought to be" and "what is", and therefore to search the few crucial emergent configurations that may make or break a system. In the case of activity-level coordination in CSCL scripts, one can observe several design tensions. These include scripted action vs. bricolage, script intrinsic vs. extrinsic constraints, and the balance between technology use driven by data capture and monitoring and technology use driven by activity-specific support. *"Scripted action vs. bricolage"* is indeed a major tension that has been studied in several contexts of fixed or mobile learning devices (Dillenbourg, 2002; Tatar, 2007). Balance has to be found in the compromise between active / discovery learning and a proper use of existing knowledge on good practices that increase the chances of effective learning. In the latter case, collaborative learning flow patterns (CLFP), i.e. computational representations of scripts such as jigsaw, pyramid, etc. have been shown to be significantly useful in several CSCL scenarios (Hernández, Asensio & Dimitriadis, 2006). On the other hand, the balance of the *real-time improvisational demands as compared with authoring effort* must also be considered. A lightly scripted scenario may require a lot of creativity and improvisation by the students, while highly planned scripts involve a resource-consuming authoring process for the teacher. In addition, *dependence on external programmers / developers* increases to the extent that technology is involved in the scripts.

This paper focuses on activity-level coordination and awareness in face-to-face activity, and examines the tradeoffs between socially-mediated and technology-mediated coordination. It aims to provide an initial exploration of such a tension in the context of the use of a significant CSCL tool in an authentic situation. The ultimate aim of this approach is to provide valuable information on the intertwining variables of real settings, point to the conflicts and the associated compromises, and even to configurations that might provide design solutions. In this case, we have opted to employ Group Scribbles (GS) (SRI International, 2007) in a case study consisting of face-to-face tutoring sessions of a project-based course on Computer Architecture.

Group Scribbles is based on a simple, research-based set of GUI elements, which help the user create and move easily between lightweight public and private arrangements of information. Among other capacities, it allows the teacher (or other user) to design, present and edit representations of processes. Since GS supports lightweight, flexible social coordination, it serves as a good candidate for the study of the aforementioned design tension. The *Group Scribbles* design stakes out a specific, and less well-explored, balance among the poles of the design tensions considered here. In particular, the support for colorful organizing backgrounds and the lack of support for canned scripts positions it much closer to the bricolage pole than the scripted-action pole of intended use. Similarly, its inclusion of few, but very firm, internal constraints (including the firm separation of public and private action, human- rather than machine-interpretable data, and uniqueness of objects) helps set the expectation that many, but not all, of the constraints must be supplied externally. Finally, in the current implementation, only such data capture as is a natural outcome of the underlying architecture is supported.

Discussion and conclusions based on the case study

The case study took place at the University of Valladolid, Spain in Fall, 2006. The context was a series of tutoring sessions in a collaborative and project-based course on Computer Architecture at the Telecommunications Engineering School. The specific topic of the tutoring sessions reported on here is "search and selection of reliable information sources" related to issues of benchmarking computer systems. The scenario integrated a combination of the Jigsaw and Pyramid collaborative learning flow patterns and it was enacted in two sessions of two hours, each involving two sets of different students (5 and 8 volunteers, respectively). The first session, *Experience1*, is entirely based on social coordination and involves both the use of paper (for collaborative activities on diagrams and conclusions) and general purpose software for Internet access, document viewing, etc., while the second session, *Experience2*, is supported by the *GS* tool. In other words, in this session, we used the tool to provide a low level of technology-mediated coordination. GS was initially set up with specific background images and sets of boards tailored for the activities. These two experiences cover an important but small range of solutions for the design tension under study. To reinforce our contrast, we are going to speculate on the expected results of a third experience, *Experience3* that uses strong technology mediation, since it can serve as a contrast point for our study. Although *Experience3* has not yet taken place expected features can be reasonably based on several previous experiences held out by the GSIC/EMIC group in similar contexts, as e.g. in (Hernández, Asensio & Dimitriadis, 2006). In *Experience3*, coordination will be accomplished through a highly prescriptive computational script, generated by the Collage editor of learning designs in IMS-LD and enacted within Gridcole, a tailorable service-oriented environment.

The data based on a simplified mixed evaluation method allowed us to analyze various aspects of the aforementioned design tension and provide evidence-based conjectures. The specific data suggest that the case study can be considered authentic, because it employs non-trivial activity flows, integrated in a meaningful way into a complex project-based and collaborative course. It also suggests that GS, as a CSCL tool, provides affordances that support and enhance activity-level coordination, as compared to the purely socially coordinated experience. It can be argued that GS' lightweight character, together with the powerful underlying metaphor and the Tuple Spaces coordination language, enabled and strengthened embodied coordination through the awareness stickers, flexibility and adaptation to emergent situations, and less need for guidance by the teacher. Social coordination was also shown to be highly effective. Its benefits include utilizing very few resources, with the notable exception of teacher creativity and improvisational ability. Additionally, we have confirmed the potential of using collaborative learning flow patterns (CLFP) i.e. good practices or formalized effective scripts, which contributed to the perception of a non-complex activity flow.

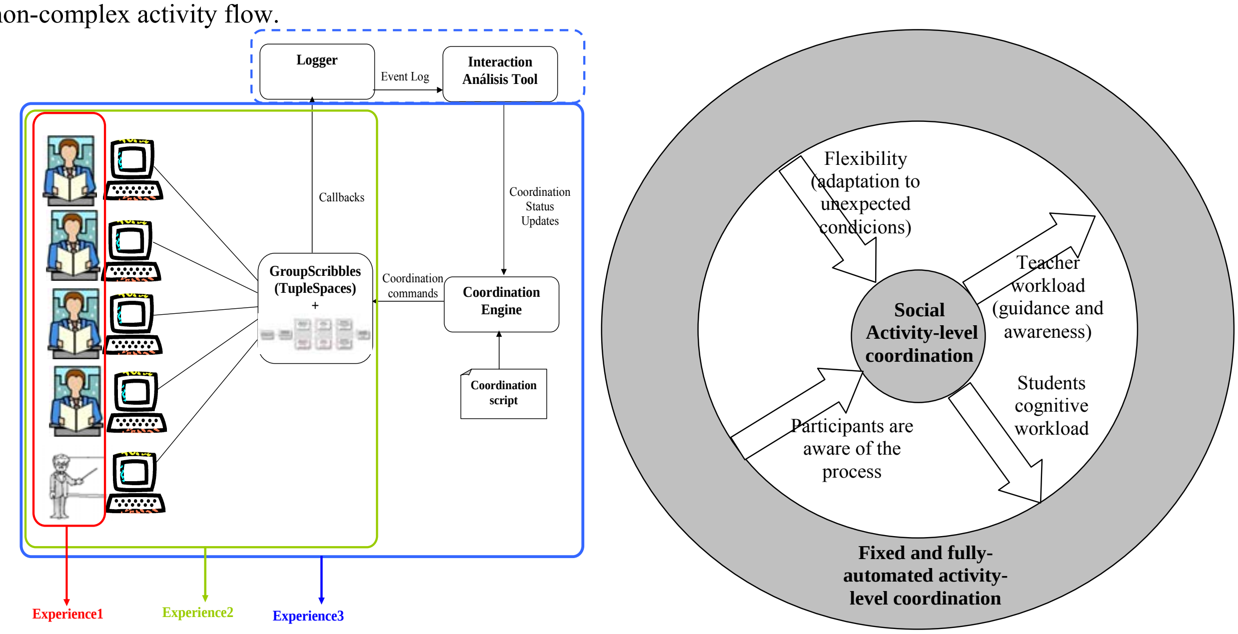

Figure 1: The envisioned architecture (left) and its relation to the design tension (right)

However, in both cases, that of GS and that of social-coordination, the role of the teacher is crucial. As anticipated in the design philosophy of GS, "the only limit is educator's creativity" (SRI International, 2007). Therefore, demands on the teacher are high in all phases of the activity: design, enactment and evaluation phases. The teacher had to design from scratch the activity flow, improvise, supervise, react, and finally monitor and analyze the experience based on "ephemeral" data. Improvisation, creativity and experience cannot be easily found among practitioners, and in any case they may pose a burden for an extensive use of lightweight CSCL tools, such as GS. On the other hand, the hope is that with time, just as with HyperCard, familiar patterns of use will emerge that will put less of a burden on the teacher. All these elements point out to the expected benefits from strong technology mediation, as the one envisioned in the third experience. Tools for design, enactment and evaluation may increase efficiency according to the engineering worldview. Based on the analysis of the design tension (see Figure 1 – right), we can point out to a new flexible architecture that encapsulates affordances of GS as a lightweight coordination technology support, and provides the possibility of using additional computer mediation. In this case, a designer or practitioner as a person involved in action / research may choose to use one or more of all the additional modules presented in Figure 1 (left).

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PhysHint: A Qualitative Study of Student's Knowledge Elaboration in CSCL

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Abstract: The poster concerns a qualitative study of student's knowledge elaboration in computer-supported collaborative problem solving. The aim of the study is to investigate whether we can use elaboration value as a measurement to insight into student's communicative artefacts in CSCL and diagnose the crux of mixed-gender collaboration.
Keywords: CSCL, problem solving, physics learning, partner gender

Introduction

Parnter gender plays an important role in dyadic collaboration, especially for high school female students in solving physics problems (Ding & Harskamp, 2006). Although mixed-gender collaboration produces more ideas and a greater diversity of proposals than single-gender collaboration (van Hiel & Schittekatte, 1998), females are at a disadvantage with respect to learning achievement (Graham, Fenwick and Derrick, 2001). In our previous research (Ding & Harskamp, 2006; Harskamp & Ding, 2006), we used Bales' Interaction Process Analysis (IPA) model to investigate students' information exchange during collaboration, and found that the presence of male students made females reluctant to put forward ideas and become less active in collaboration. But partner gender has no significant influence on males' interaction. Students have different exposure to the use of computer technology. The computer itself is arguably a disadvantage for females because computer-mediated communication (CMC) is historically stereotyped as a male dominated domain.

Although numerous research has investigated females'communication styles in single- and mixed-gender collaboration, very few research affords an insight into students' knowledge elaboration, especially in the field of Computer-Supported Collaborative Learning (CSCL). According to Sutherland (2002), elaboration of knowledge is the key factor for students' problem-solving learning. Therefore, we embark this qualitative study to verify whether we can use message elaboration as a measurement to insight into students' cognitive activities in CSCL and diagnose the crux of mixed-gender collaboration.

Knowledge Elaboration in CSCL

In collaborative problem solving, group is the learning agent (Suthers, 2006). The joint knowledge elaboration is made up of numerous meaningful artefacts, such as utterances, visual representations. Students learn more from each other through elaborative explanations than simple forms of exchanges (Webb & Farivar, 1999; van der Meijden & Veenman, 2005). The knowledge elaboration perspective which emphasizes the cognitive process of collaborating individuals states that learning occurs when students are involved in reflecting, correcting, extending and restructuring partner's way of thinking (King, 1999; Webb & Farivar, 1999; van der Meijden & Veenman, 2005). The knowledge elaboration might differ across participants. We presume that the individual difference in knowledge elaboration could be reflected by the content of individual communicative artefact. Looking into students' communicative artefacts, we might deduce whether they are elaborating their knowledge and what kind of relationship exists between the collaborating individuals' elaboration process.

CSCL can make students' ideas visible and preserve them in a shared context. Firstly, it is regarded as a way to deepen students' talk and turn their transitory talk into visible artefacts for reflection; Secondly, in CMC, as Rutter (1987, p.74) states that "cuelessness leads to psychological distance, psychological distance leads to task-oriented and depersonalized content, and task-oriented depersonalized content leads in turn to a deliberate, unspontaneous style and particular types of outcomes." However, it is also argued that the reduced shared context is expected to have reduced utility (Suthers, 2006) because the shared context represents the multiple facets that make up the participants' identity, which facilitates the negotiation of interpersonal questions.

Problem-solving task is a goal-oriented task. Students communicate with each other in order to accomplish a set of goals and sub-goals. Thus, a communicative artefact is not merely a simple expression of students' knowledge or understanding, but connected with each other to construct a meaning jointly. While analyzing, we should relate it to the context of joint knowledge elaboration. If we define the first artefact which students exchange as the initial state and the subsequent one as meaningfully interrelated, we might plot the track of the joint and individual elaborations in a sequential analysis.

Research Question

Focusing on students' online communicative artefacts, is it possible to use elaboration values as a measurement to find differences of knowledge elaboration between single- and mixed-gender collaboration in CSCL?

Methodology

The computer program "PhysHint" aims at improving secondary students' problem-solving skills in physics. It was compiled with SQL to facilitate an online collaboration in physics problem solving. For instance, a dyad of students work together on a moderately-structured physics problem synchronously. They can communicate in the *Chatting Section* and illustrate the variables in the *Drawing Section*. What student A draws is automatically shown on student B's computer. To strengthen and structure students' interaction, we provide five "*Hints*" for problem solving. Different students read different hints so that they have to exchange what they read. In the end, they input their answers in the *Answer Section* for an evaluation by the computer. After that they are given the *Worked-out Example* to check the details.

Six secondary school students (3 girls & 3 boys) participated in the five-day experiment. There were three dyads: one mixed-gender dyad and two single-gender dyads. Prior to the experiment, they were given a twenty-minute pre-flight training about how to use the program. Then they were separated with a board to avoid talk or eye-contact with each other. The whole experiment was overseen by the researchers. We endow each communicative message an elaboration value according to its content (Table 1):

Table 1: Sample of Elaboration Values.

Number	Description	Example
+1	messages elaborating on knowledge and contributing to the final solution.	Student A: What is the Newton's 2nd law? Student B: F=m*a
0	messages remaining on the previous elaboration level	*(Student B: F=m*a)* Student A: Yeah.
-1	messages that are irrelevant to the task and distract the problem solving task	Student B: You will go to Rome, won't you?

Results

Peter & Henry (male-male dyad)	Sandy & Karol (female-female dyad)	Ralf & Jenny (mixed-gender dyad)

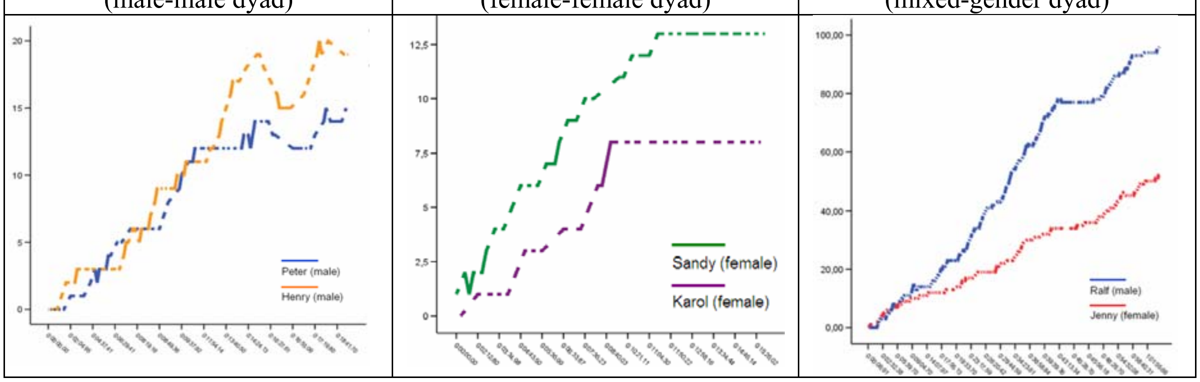

Figure 1. Individual Knowledge Elaboration in 3 dyads (*students are pseudonymous*)

As we add up students' individual elaboration values and plot them sequentially, we are able to illustrate the process of knowledge elaboration in each dyad (Figure 1). Three dyads exemplify three types of relationship of individual knowledge elaboration: *Cross* (in Peter& Henry dyad), *Parallel* (in Sandy & Karol dyad) and *Divergent* Elaboration (in Ralf & Jenny dyad). We look into the mixed-gender dyad and zoom in the episode that Ralf and

Jenny diverge in knowledge elaboration. After examining their communicative artefacts, we find two problems that lead to the divergent knowledge elaboration: incoherence in CMC and Ralf's overlook of questions.

Discussion

The study shows that the elaboration value can be a workable measurement to trace students' cognitive activities in CSCL and diagnose the problems in dyadic collaboration. In the future, a quantitative study involving more students and a longer period of experimental time are expected.

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An Innovative Approach for Fostering Computer-Supported Collaboration

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Abstract: Computer-supported collaboration is still problematic with regard to the interaction between spatially distributed group members. In this paper, an innovative approach to tackling this problem is presented. This approach is based on fostering "knowledge and information awareness" that is defined as awareness of a group member with regard to task-relevant knowledge and information underlying this knowledge of his/her collaborators. An experimental study described in this paper confirmed the efficiency of knowledge and information awareness on computer-supported collaborative problem solving.

Knowledge and Information Awareness to Tackle Problems in CSC

Computer-supported collaborative learning (CSCL), defined as "practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts" (Koschmann, 2003, p. 18), is becoming increasingly important. In the context of CSCL, not only are learning settings in focus, but also settings that are learning-relevant, like *computer-supported collaborative problem solving* which is addressed in this paper. Results of empirical research confirm the potential of computer-supported collaboration (CSC): For example, it has been shown that learners in such settings may make higher quality decisions and may be better in idea generation (Fjermestad, 2004). However, research results also show that efficient CSC is not easy to achieve: For example, according to Janssen, Erkens, Jaspers, and Broeken (2005), groups in CSC settings often have communication and interaction problems. In the CSCL research community, there are different strands of research addressing such problems of CSC, e.g., approaches that aim at enhancing different kinds of group awareness. Following Gross, Stary, and Totter (2005) group awareness is defined as "consciousness and information of various aspects of the group and its members" (p. 327). However, in the literature, there is no consensus about how this term is defined. Mostly, the meaning of awareness refers to social or action awareness (e.g., Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003). However, in knowledge-rich and information-rich situations, these awareness types may not be enough to support effective CSC, but "*knowledge and information awareness*" (KIA) is needed, which is defined as awareness of a group member regarding both the knowledge and the information underlying this knowledge of his/her collaborators (Keller, Tergan, & Coffey, 2006). KIA can be fostered by means of using advanced digital concept maps that have not only the potential to represent conceptual *knowledge* (i.e., concepts and their relations), but also *information* underlying a concept (e.g., an image or an explanation of a concept). It is suggested that being aware of the knowledge of others and the information underlying this knowledge, may help cooperative problem solvers in shared knowledge-construction and problem-solving tasks. This assumption is based on the *theory of transactive memory* (Wegner, 1986). According to this theory a transactive memory system is a set of individual memory systems combined with the communication between the group members. In the present project, KIA is supported by means of an environment visualizing knowledge and information visualizations of the collaborators by means of digital concept maps. It is assumed that KIA is helpful in a computer-supported collaborative problem-solving scenario, because it could be expected that KIA has a positive impact on interaction, especially on communication and coordination and, therefore, also on collaborative problem solving: Following Clark and Brennan (1993), shared understanding in communication is crucial for individuals working in a group. Making visual representations of the knowledge structures and the underlying information of each group member available to the group should facilitate shared understanding and, thus, communication. Moreover, it has been shown that information that is shared by all group members is often mentioned in group discussion, while unshared information that is known by only some group members, mostly remains unmentioned (e.g., Stasser, Vaughan, & Stewart, 2000). However, such unshared information could be important for problem solving. Therefore, it is important to also recognize unshared information. By comparing the external knowledge and information representations of the collaborators, group members can easily recognize which knowledge and information is shared and which is not. This should have a positive effect on group coordination. In addition, it is assumed that the possibility to view the knowledge and underlying information of other group members provides a kind of affordance for each individual to make use of these representations (Suthers, 2005).

Experimental Study

The experiment investigated whether groups using an environment for fostering KIA collaborate more efficiently in problem solving tasks than groups that do not have a KIA environment.

Method

Participants: Participants were 90 students (58 female, 32 male) of the University of Tuebingen, Germany. Average age was 24.47 (SD = 3.83). The students were randomly assigned to the experimental condition (N = 15 groups) or to the control condition (N = 15 groups).

Materials and Procedure: The participants worked in groups of three students sitting in separate room sections. They could not see each other, but could speak with each other. The domain was about caring for a fictitious kind of spruce forest and consisted of several concepts, relations, and information elements underlying the concepts. These elements were evenly distributed among the three group members. At the start of the study, *control variables* (e.g., computer experience) were measured by a questionnaire. Afterwards, the participants had to *practice the use of CmapTools* (http://cmap.ihmc.us/). At the outset of the *individual phase 1* (23 minutes), the group members worked separately, accessing the information elements in their own information window on the left side of their desktop and structuring their information and knowledge in form of concept maps in their own working window on the right side of their desktop. In the *individual phase 2* (5 minutes), each participant of the control group examined his/her own map. Each participant of the experimental group, however, could also see the maps of his/her collaborators. After this activity, there was a *manipulation check* to measure the amount of KIA acquired (15 items). In the *collaboration phase* (40 minutes), the group members collaborated on solving two problems, i.e., which pesticide and which fertilizer they would use. To solve these problems, the participants needed to compile their knowledge and information. To do this, they used a shared working window to create a common digital concept map. During this phase, they could speak with each other. In the control condition, the participants could only see their own working window and the shared working window. In the experimental condition, the participants also saw the individual maps of their collaborators to become aware of the knowledge and information their collaborators had. Finally, a *knowledge test* was used to measure the knowledge the participants had acquired and a *questionnaire* was used to assess, e.g., difficulties regarding collaboration.

Design and Dependent Measures: The analysis was based on a comparison of the *experimental condition*, in which the groups were provided with an environment for fostering KIA, and the *control condition*, in which the groups worked without it. The dependent measures were the *domain knowledge* (30 multiple-choice items)*, the quality of the common concept map* created in the collaboration phase, the *quality of the group answers to the two problem-solving tasks,* and *process-related measures.*

Results and Discussion

In all analyses of variance reported here, the control variable "experience in creating computer-based graphics" was used as a covariate, because of a significant difference between the control and the experimental condition. All analyses presented here are based on group level, i.e., the group values are calculated as means of the values of the individuals of a group. This was necessary, due to the fact that the members of a group are not independent of each other. *The first series of analyses* confirmed that the groups in the experimental condition acquired KIA by using the KIA environment: The analysis of the *manipulation check* after the individual phase showed that the experimental groups achieved on average 58.75% of the score in tasks asking for information that only one of the other group members had and 59.44% of the score in tasks that asked for information that only the two other collaborators had. The analysis of the questionnaire items (rating scales: 1 = "no agreement" and 5 = "complete agreement") showed, e.g., that the experimental groups agreed on average that it was helpful to have access to the maps of the collaborators ($M_E = 4.27$; $SD_E = 0.75$).

The second series of analyses explored the impact of the use of the KIA environment on the dependent measures. The questionnaire measuring *process-related aspects* showed that participating in the study was more stressful in the control groups ($M_C = 3.2$; $M_E = 2.7$; $F(1,27) = 4.66$; $MSE = 0.28$; $p < .05$), although the experimental groups had more problems regarding the use of the different windows on the desktop ($M_C = 1.8$; $M_E = 2.2$; $F(1,27) = 6.25$; $MSE = 0.25$; $p < .05$) compared to the control groups. The analyses of the *log files* with regard to uptake events, i.e., events in which group members take up and build on prior contributions (Suthers, 2006), confirmed that there were significantly more intersubjective uptake events in the experimental groups than in the control groups ($M_C = 0.5$; $M_E = 3.3$; $F(1,27) = 18.20$; $MSE = 2.93$; $p < .001$). KIA seems to foster intersubjective knowledge construction. The analysis of the *knowledge test* revealed, e.g., better performance for the experimental groups regarding the *knowledge on domain relations* that were shared by a participant collaborator dyad compared to the control groups ($M_C = 2.1$; $M_E = 2.4$; $F(1,27) = 4.2$; $MSE = 0.14$; $p < .05$). Moreover, the analyses revealed that the experimental groups gained higher values in *knowledge regarding information underlying a concept* that is only shared by the other collaborators ($M_C = 2.6$; $M_E = 2.9$; $F(1,27) = 4.17$; $MSE = 0.41$; $p = .05$). These results provide evidence of the efficiency of the KIA environment. Regarding the *quality of the group maps*, there were no differences between the conditions regarding the number of correct relations and concepts (nodes: $M_C = 12.9$; $M_E = 12.6$; $F(1,27) = 1.71$; $MSE = 0.46$; $p = .20$; relations:

$M_C = 23.3$; $M_E = 21.5$; $F(1,27) = 1.81$; $MSE = 22.21$; $p = .19$). However, it seems that the experimental groups tried to avoid information overload in their maps: There were more intersections of relations in the group maps of the control groups than in the maps of the experimental groups ($M_C = 15.3$; $M_E = 9.0$; $F(1,27) = 4.84$; $MSE = 51.88$; $p < .05$). With regard to the *problem-solving tasks*, the experimental groups tended to be more confident that they had solved the two tasks correctly (pesticide problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.38$; $MSE = 0.47$; $p = .077$; fertilizer problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.17$; $MSE = 0.57$; $p = .086$). This subjective estimation of the participants was partly mirrored in objective results, namely in the group answers given: Regarding the number of correct answers to the pesticide problem, the data did not show a significant difference between the conditions (Pearson-$\chi 2$ (2) = 3.20; $p = .20$). However, regarding the number of correct answers to the fertilizer problem, the experimental groups attained a marginally higher performance compared to the control groups (Pearson-$\chi 2$ (2) = 4.9; $p < .087$).

Summary

The presented study demonstrated that computer-supported collaborative problem solving can be supported by enhancing KIA. In this study, an experimental condition using an environment for enhancing KIA was compared to a control condition that ran without it. The analyses showed that the experimental groups acquired a substantial amount of KIA by using the KIA environment. Results further indicate that participating in the study was more stressful for the control groups, although the experimental groups had more difficulties in using the windows. Therefore, the benefit of using a KIA environment seems to be great enough to compensate for the higher cognitive load caused by the need to use more windows on the screen. By analyzing the log files, it could be confirmed that, in the experimental groups, more intersubjective meaning construction took place than in the control groups. Moreover, the analyses showed that the experimental groups achieved higher performance in both knowledge regarding content information that was only shared by the other collaborators and knowledge regarding relation information that an individual and another collaborator had. Regarding the quality of the group maps, there was no difference in the quality in the sense of correct nodes and relations between the conditions. However, the analyses showed that the experimental groups tried to avoid information overload in their map. Most importantly, the study demonstrated that using a KIA environment was helpful for problem-solving performances.

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Helping Teachers in Designing CSCL Scenarios: a Methodology Based on the LDL Language

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Abstract: When teachers prepare learning activities to be carried out by learners within web learning environments, they encounter two main problems: the modelling and the technical ones. The modelling one is nowadays regarded as being the most important, both in CSCL and Learning Design. We have defined a methodology to help the teachers to model. It is briefly presented here. It is subordinated to the educational modelling language used to produce the models: LDL.

Introduction

There is a broad acceptance in the CSCL community that collaboration is not that spontaneous and that learners need to be scaffolded in collaboration activities. The teacher has to provide them with some guidance to be sure that collaboration will be effective and efficient. Researchers have thus recommended carrying out a scripting phase before the performance of the activity, during which a description of the future activity will be produced.

In order to support this preparatory task, we have defined an educational modelling language (EML) called Learning Design Language (LDL) (Martel et al., 2006a). It is intended for teachers or instructional designers. It has been created to allow them to describe and specify collaborative pedagogical activities on internet. The ambition of LDL is twofold: on the one hand, it provides the teachers and instructional designers with simple means to build the formal description of whatever kind of pedagogical activities and to combine them; on the other hand, it allows the teachers to be able to transform easily these formal descriptions into effective online activities whilst considering the technical environment in which they operates (i.e. the resources available on their school network and on internet).

Using LDL during the preparation phase leads the teacher to create a *scenario*. A scenario is a very codified and formal description of a future activity. It can be considered as a *specification* of this activity. Building such a specification is not that easy. We have defined a methodology and a graphical notation to help the teachers build a scenario. The methodology is subordinated to the LDL language. It is presented briefly in what follows.

The proposed methodology

The proposed methodology distinguishes two steps clearly. Step1 aims at building an informal scenario (a narrative text). Indeed, we think that it is not possible to ask a designer to produce a formal description directly. Step2 aims at formalising this informal scenario. When analysing a learning situation, it is possible to identify activities of different types that are interwoven. We consider four types of activities:

- the *learning type*. Activities of this type are the heart of the learning. Learners manipulate the resources put at their disposal. They produce contents related to the learning objectives. They work individually or collaboratively.
- the *observation type*. During activities of this type, the teacher observes the ongoing learning activities with the aim of supervising and regulating their progression.
- the *assessment type*. Any learning activity is preceded, associated with or followed by at least one assessment activity. The place of the assessment activity in the overall learning flow depends on the kind of assessment desired by the designer (diagnostic, formative, summative, etc.) (Durand & Martel, 2006).
- the *organisational type*. Activities of this kind are dedicated to organisation problems: resources and tools are made accessible; instructions are given; if needed, groups are created; the other activities are started.

We propose to regard these four types of activities as basic elements that are constitutive of every learning activity to model. The overall learning activity results from the combination and the interrelations of these activities. Being activities per se, they can be modelled as independent scenarios. Building the formal scenario of a learning activity is thus no longer a matter of defining a unique scenario, which encapsulates everything. It becomes a matter of defining *at least four* scenarios, corresponding to the four different kinds of activities identified. As a consequence, it becomes a matter of describing the relationships between these scenarios. It is also a matter of describing each scenario in terms of the concepts proposed by LDL. Once again, this leads to splitting the methodology into two phases : (1) identifying the activities and (2) modelling each identified activity.

Formalizing the informal scenario: (1) Identifying the activities

At this stage, the designer has first to analyse the overall activity to identify the activities that constitute it and that correspond to the four types of activities mentioned above: organization, learning, observation and assessment. This has to be completed with the description of who is to be involved in each activity. This is a matter of identifying the *roles*. Furthermore, for each activity, the designer has to identify the participation modes.

What is meant by "participation modes" is the overall way participants will exchange and interact in an activity. They describe the kind of situation a designer wants to carry out with her/his students. They allow one to distinguish *individual participation* from *collaborative participation*. The former is characterized by participants having individual activities and no relationship with each other, the latter by participants acting in the activity as interdependent and engaged partners involved in a common quest. In collaborative participation, we distinguish *frontal* situations from *open* ones. In frontal situations, participants have individual activities and no relationships with the other participants, except with a person having a particular role who oversees, stimulates, coordinates and controls. A course at university in a lecture hall is a typical frontal situation. In open situations, participants can cooperate freely with the other participants. It is the case for example of a panel session in which participants are invited to discuss and express freely their opinions and points of view. Note that in real educational practices, these various forms can be combined with each other to produce hybrid educational situations that can evolve over time.

Once the designer has identified the activities and the participation modes for each of them, s/he has to position these activities with respect to each other. This means that s/he has to:

- define the learning flow. This leads to both the building of the activity schedule (specification of the order according to which the activities will have to be performed) and the definition of synchronization points between these activities;
- define the objects the activities may share. Two kinds of objects can be shared: *arenas* and *positions*. Both are LDL concepts. *Arenas* represent the places where the activities and exchanges will take place (activities are situated). A *position* reflects the participants' reactions and perception of the activity. It is a general concept which covers different notions such as the participant's point of view (for example, "I have finished this exercise"; "we have answered this question"; "this exercise is too complicated"), her/his availability, a mark (we consider it as the position of a teacher on a learner's work), etc.

Formalizing the informal scenario: (2) Modelling each activity

It is time now for the designer to go deeper into each activity and to build a model (i.e. a scenario) for each of them. This is done by using LDL concepts. We have made a particular analysis of what a learning activity is. From our point of view, it is not a process which can be broken down into a succession of tasks to be carried out. Rather, we draw a parallel with a conversation, in which locutors speak to their interlocutors, who make an interpretation of what is said and may react in turn (Austin, 1955). Just like a conversation, we consider an activity as *a set of exchanges and interactions* between the users involved (the participants). And as in a conversation, every exchange *involves at least two participants*: an *addresser* who acts and whose actions are aimed at an *addressee*. It should be noted that the addresser and the addressee may be the same person in a given exchange. The exchanges may be *organized and structured* by the designer in *a given learning context* (the activity is *situated*). This context includes not only adequate learning objects (contents and services) and the learning objectives but also a set of *rules* that scaffolds the activity. In addition, an activity progresses through individual and collective *positions* taken by the participants within their exchanges. These positions have an influence on the progress of the activity, as they are indicative of the participants' reactions and perception of the activity. So the teacher observes them with the aim of adapting the situation, by modifying the context, the exchanges or even the way exchanges are structured.

LDL has been defined within this particular interactional vision of learning activities. It also takes into account their intrinsically evolutionary nature and the need for observation and regulation. Within this vision, designing a scenario consists in describing (1) what the participants' interactions will be, how and when these interactions will be connected throughout the activity (this is represented by the *interaction* and *structure* concepts in LDL), (2) where the activity will take place (the *arena* concept), (3) who the participants in the activity will be (the *role* concept), (4) the rules the participants will have to comply with (the *rule* concept) and (5) what the consequences of the participants' actions and points of view on the activity will be and how they will be able to express these points of view (the *position* concept, which is linked to the *observable* one).

Discussion and Conclusion

Once the formalisation work has been completed, the designer has built several diagrams that specify the scenarios and the learning flow between the activities modelled by these scenarios. As the methodology is based on LDL and involves the description of scenarios by means of LDL concepts, it is possible to make an automatic translation of the resultant diagrams into an LDL-equivalent codification (in an xml binding form). Then a computer is able to "understand" this codification. Thus it is possible to operationalise the scenarios and execute the corresponding activities in a given web learning environment, chosen by the teacher who wants to carry out these activities with her/his students. This is carried out by LDI (Learning Design Infrastructure), an infrastructure which deals with both operationalisation and execution of LDL-scenarios. LDI has been developed by Pentila Corp., which is our main partner in this project (see http://ld.pentila.com. Many thanks in particular to Steve Giraud).

Our approach is different from what is usually done in CSCL research. The usual approach consists in embedding scenarios in CSCL tools. The source code of these tools has to be modified by computer engineers to integrate the scenarios. In our approach, on the other hand, we propose to keep the scenarios *outside* the tools. Then the scenario, formalised in LDL, made executable by LDI, becomes a means of organizing the use of whatever services and Learning Objects that could be used in learning activities. This approach has several advantages. First, it is easy to reuse scenarios. In (Harrer et al., 2006) a similar argumentation is used applying IMS/LD for the scripting of CSCL activities. Second, people who have to deal with learning activities and scenarios do not have to concern themselves with the technical problems related to implementation. Third, the time between the moment when the formal scenario is produced and the moment when it can be executed on a computer is considerably reduced. This could lead to a new potential use of scenarios, which supplements the ones listed by (Miao et al. 2005): the possibility for CSCL researchers to carry out their experiments more easily and more quickly.

There is another difference between our propositions and the work usually done in CSCL scripting. Instead of building a single scenario that encapsulates the overall complexity of a given learning activity, we rather propose a modular approach. It consists in considering every learning activity as a composition of activities of four types: learning, organisation, observation, assessment. The advantage is threefold. First, it reduces the complexity of the overall situation to be modelled. Second, it provides the designer with some guidance. Third, as it leads to a componential approach, it facilitates the reuse and the adaptation of the scenarios produced.

The methodology was practically tested on the example of the planet game, a case study that was used as a benchmark/competition in a workshop we organized during last ICALT (Martel et al., 2006b, Vignollet et al., 2006). We now need to validate it. For that purpose, we have to do some experiments with teachers, giving them the role of "scenario designer". If we wish to do that in the best conditions, we in fact have to provide an authoring tool to support the design process. This tool has to be simple and intuitive enough to be used by teachers. We have specified such a tool. It is currently under development and should be operational next summer. This will allow us to start a validation phase with teachers and, why not, CSCL researchers. Are you interested in this ? …

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Illegitimate Practices as Legitimate Participation: Game Cheat Sites in a Teen Virtual World

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Abstract: Much research has described the various practices of gaining access and participation in multi-user game communities. Cheat websites that are a prominent part of the game culture and industry have been debated because of their illegitimate nature but received little attention in terms of their educational value. In this paper we analyze the cheat sites created by players for a teen virtual world called Whyville.net, which encourages youth ages 8-16 to participate in a range of social activities and play casual science games. Analysis of a sample of 257 cheat sites resulted in typologies for both the cheats and sites in terms of quality and quantity of science content. A case study of an especially active cheat site and analysis of player-written articles in Whyville's newspaper illuminate the illegitimate and legitimate aspects of cheating in this virtual world. Implications of these findings as cultural artifacts of the game community and as guides for designing informal online learning activities are discussed.

The phenomenon of cheating is gaining increasing traction in discussions of gaming practices in multi-user virtual environments (MUVEs). The debate whether cheats are illegitimate has largely been influenced by industry practices to publish short cuts in their magazines, thus legitimizing the dissemination. Even among players there are no clear standards on what counts as cheating and what the repercussions are. According to Mia Consalvo (in press) cheating provides players with *gaming capital*, which can be defined in this context as "being knowledgeable about game releases and secrets, and passing that information on to others. It's having opinions about which game magazines are better and the best sites for walkthrough on the Internet". One aspect of cheating that has received little attention so far is cheat sites, player-generated websites where players share strategies (or answers if applicable) for solving problems in the virtual games. We approached the investigation of cheat sites for Whyville with the following questions: How do Whyville players design cheat sites? What does a site consist of, how do they change over time, who creates them and what are their motivations? Is there any science displayed in the cheat sites stemming from Whyville? If so, what kind of science concepts and skills are targeted on these sites? Moreover, what does this reveal both about the designers of the sites and the nature of the science games themselves?

Research Approach

For our investigation of cheat sites, we drew from two sources, cheat sites available on the Internet and the archive of news articles in *The Whyville Times*. We sampled a subset of 15% of the 257 sites (38 in all) and ruled out sites that were scams (asking for people's passwords in exchange for an advertised raised salary) and sites that only talked about cheating but did not offer answers or directions. Of the remaining sites, 13 were legitimate cheat sites. In a first step, we evaluated the identified cheat sites using the typology developed by Salen and Zimmerman (2004). In a second step, we developed a classification system that delineated the types of sites according to the quality and helpfulness of the cheats (from comprehensive to copies of other cheat sites) and the kinds of cheats listed for various games as they relate to the science in the games (from a listing of answers to more qualified descriptions and illustrations). We also searched in the archive of *The Whyville Times* newspaper and identified over 100 articles that discussed cheating in Whyville. We used these articles to evaluate the ethical discussions surrounding cheating in the world of Whyville.

Illegitimate Cheat Sites outside Whyville

The large number, 257, of cheat sites about Whyville found on the Internet is a clear indication of Whyville's popularity. When we applied Salen and Zimmerman's (2004) typology of cheats, we found that cheat sites for Whyville incorporated all of the types they identified. We have outlined their definitions in the table below and listed parallel types of cheats found on Whyville sites (see Table 1).

Table 1: Typology of Cheat Sites

Cheats	Description	Whyville Cheat Sites
Easter eggs	Special secrets hidden in the game by designers	Unlisted spaces within the game, e.g., Jupiter, Disco Room, the Newspaper
Cheat codes	Actual codes written up by the designers (providing immortality and other benefits)	Indirect parallels in Whyville: - "teleport Jupiter" to get to Jupiter, - "earmuffs now on" to listen to people whispering online
Game guides and walkthroughs	Step-by-step instruction for finishing a game	Most common cheat on sites: - How to play through a game, - Answers to games - Illustrations for games
Workarounds	'Legal' ways of working around game structures	- E.g. House of Illusions: walking through all rooms without looking at anything - Setting up another account to get more clams - Selling or buying others' extra accounts
True cheating	Really and truly breaking the official site rules (e.g. multi-sessioning)	Stealing others' accounts through scams that ask for usernames and passwords
Hacks	Intervention on the level of a computer code	Codes that deposit many clams in account (now expired – we were unable to test these)
Spoil-sport hacking	Intervening in a way that brings down the game and is not for the purpose of being involved in the games.	Stealing others' accounts by hacking into the system (rumors of this happening but unstudied by the authors)

We examined in detail Gamesite2.net (a pseudonym for the site), one of the more comprehensive sites that contained Easter eggs, cheat codes, game guides and walkthroughs, and workarounds as described above. The site itself noted that it had on average 200 visitors a day, in addition to 34 registered users (as of 8 October 2006). It began in mid-2004 and, according to the history posted on the site, went through several versions until in mid-2006 it started regaining popularity. The site owner and designer, a 14 year-old young man, and his three administrators, posted new messages on the home page of the site roughly four times a month, not including numerous responses to messages on the forums. On the home page, the site designer wrote regular updates about "our" progress in developing/researching new cheats for new games or versions of games in addition to cheats or hints about things that were not game-related (in other words not related to a game that would be rewarded with clams). Other Whyville players posted comments about cheats they had figured out in a game, pleas for more or better cheats, and praises for the help offered on the site. While the site designer and his site administrators officially managed and posted the cheats, the activity of gathering and synthesizing the cheats was a collaborative effort, and the leaders gave credit to those who had assisted with various parts of researching and developing the cheats.

In addition, the site was not neutral about what was appropriate behavior on the forum. The owner closely watched forum postings for inappropriate material and advertising of other sites: "every one who swears a lot, spams, or cusses… will be banned." Looking through the forum, one can see many times when messages or parts of them have been locked or erased by the owner. In addition, other forum participants pointed out things that they thought rude about some comments left on the site. For instance, when one user complained that there were not enough cheats or that the site did not help him enough, another user replied that the site owner did a lot of work on others' behalf and we should be grateful for the help he provided. While the site recognized that scams occurred, it did not support them and purposefully tried to distance itself from that practice. Besides cheats for science games, the site also provided cultural tips and insider knowledge about Whyville. These included how to access unlisted social spaces (teleporting), how to act and talk on Whyville, where to shop for face parts, how to avoid being hacked, and information about what kinds of people hang out in which locations on Whyville. The site even included non-science game cheats such as how to make your Scion (virtual car on Whyville) invisible, answers to *The Whyville Times* weekly crossword, and a simple computer code that makes throwing projectiles faster. The site even provides "free advertising" for stores that Whyvillians design (Whyville itself only offers paid advertising).

Legitimate Discussions about Cheating within the larger Whyville Community

Cheat sites about Whyville, like the one we presented above, are not a hidden phenomenon; in fact, they are openly discussed in *The Whyville Times* newspaper that constitutes a community forum. Just as in the commercial gaming world (Gee, 2003), cheating is a hotly debated topic in Whyville and the newspaper articles criticize the practice of using cheat sites to increase salaries illegitimately: "when just one person uses cheats it could affect our whole town" (Ickamcoy, 2003). Of the over 100 articles that mentioned cheats in *The Whyville Times* from 2000-

2006, roughly 10% were explicit warnings against scams, reporting on the many imaginative ways Whyvillians have tried to procure others' passwords with the promise of raising their salaries, giving them makeovers, and even claming to be site designers. Another 30% more generally condemned cheating in salary-raising games, i.e., using cheats found on cheat sites. Others (20%) discussed cheating in the Smart Cars races where instead of going around the track in a traditional race, some players would immediately turn their cars around and cross the finish line, thus triggering a win. These particular articles constituted a long, multi-year discussion about whether this was a valid way to win at Smart Cars. Some utterly denounced the practice while others, including the *Times* editor considered it a rather clever method. Still further, another 10% of the articles concerned cheating in dating relationships, some of them asking whether it was cheating if one had one boyfriend in the 'real' world and a different one in Whyville. Another 20% concerned issues with ballot stuffing, creating multiple accounts in order to have more votes for oneself in elections for Whyville senator or prom king/queen. And a final 10% described and rebuked other forms of cheating on Whyville, including the provocative "stealing from Grandma" referenced in the title of this paper.

Discussion

Our examination of cheat sites in Whyville, an informal free MUVE for teens, took inspiration from what researchers had observed in large-scale online games. Our analyses indicate that the Whyville cheat sites are as sophisticated in number of different cheat types as those for commercial games. The cheats cover the whole gamut: from helping players to make more clams to cheating players out of their clams. If anything, the presence of this large number of cheat sites can be seen as a simple measure of community participation. The players in Whyville are interested in finding out about short cuts and pointers and provide the audience. Thus there is an incentive for designers to create, and even copy, these sites. Beyond purely altruistic motives we can suspect that hosting a site as a designer but also knowing about good ones as a player might just constitute what Consalvo (in press) had in mind when she coined the term "gaming capital." As in many other games, knowing shortcuts represents some form of insider knowledge and thus positions users and designers of cheat sites as legitimate participants of the Whyville community. We found that the cheat sites reveal a great deal about their designers. All are invested in Whyville, in promoting others' success on Whyville, and in displaying their knowledge of Whyville. They view the object of the 'game' as getting a salary to buy face parts and participate in the larger Whyvillian culture. In fact, they value the morals of Whyville as displayed in qualifiers to their chat cheats, asking viewers to read carefully and understand the principles behind the questions. Still further, they have taken the time to learn the inside secrets of Whyville. In addition, the designers often do substantial research to develop their sites and learn how to complete science games. This includes technological research (web development, html, short codes) and scientific research (illustrations of spectra, theories about spinning fast).

In commercial games there are financial issues at stake that place the discussion about cheats in a more economic framework. When, for example, gamers are paid to play certain characters because their possessions can be sold on eBay to other players (Steinkuehler, 2006) or when players purchase bots to accumulate possessions for their avatars, the gaming capital acquired through short cuts has tangible monetary equivalents (Castronova, 2005). In Whyville.net this aspect just entered in November 2006 in game play when the company started offering clams, Whyville's currency, for sale in terms of dollars. It will be interesting to see in which ways the typology and nature of the cheat sites we have investigated will change within this new economic landscape that now provides different incentives for using cheats.

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Tracing Insider Knowledge Across Time and Spaces: A Connective Ethnography in a Teen Online Game World

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Abstract. In this study our goal is to conduct a “connective ethnography” that focuses on how gaming expertise spreads across a network of youth at an after-school club that simultaneously participates in a multi-player virtual environment (MUVE). We draw on multiple sources of information: observations, interviews, video recordings, online tracking and chat data, and hundreds of hours of play in the virtual environment of Whyville ourselves. By focusing on one particular type of insider knowledge, called teleporting, we traced youth learning in a variety of online and offline social contexts, both from friends in the club and outside members of Whyville. We elaborate on the unplanned social events that served as instigators for peaks in learning activity and the methodological challenges underlying the synthesis of diverse types of data that allowed us to follow youth across multiple spaces and times.

With the growing popularity of online games, discussions about their educational value have been initiated among researchers, practitioners, and policy makers (Glazer, 2006). There is an increased need to more fully understand these complex communities as promising models for learning and literacy (Gee, 2003). Though learning to participate in any of these multiplayer game communities can be quite overwhelming and confusing, there are only few first person accounts of how newcomers get access to insider knowledge (Steinkuehler, 2006). When we started studying an after-school club where twenty-one 9-12 year-olds came regularly to play in a multi-player online game community called Whyville, we were intrigued with the ways that they helped each other to navigate the geographical intricacies of the site and how the participants subsequently appeared to become peer teachers in their own right (Ching & Kafai, in press). In addition, it became clear that learning took place in both online and offline locations as well as between club members and within the larger world of Whyville. Our questions for this study became: How did club members learn insider knowledge important to socializing on Whyville and how did this spread throughout the club? Secondarily, how could we trace this learning across both virtual and physical spaces, and between the club community and the larger Whyville community? Finally, what can we learn from the informal teaching and learning practices among peers that could positively impact the design of technology that blurred the boundaries between virtual and physical spaces? In order to answer our questions, we had to draw on new methodologies that studied both online and offline activity, inside and outside of club time.

Research Background

Our research draws on two existing but distinct bodies of research about multi-player online communities. The more prominent and larger body has focused on online gaming contexts, conducting ethnographies of gaming communities (Steinkuehler, 2004; Taylor, 2006; Turkle, 1995; Yee, forthcoming). In these studies, researchers used ethnographic and interview methods to document and analyze players’ interactions, preferences, and reflections as they relate to their online game play. The second smaller body has examined the offline gaming contexts in places such as after-school clubs, individuals playing at home, and especially cybercafés (Lin, forthcoming; Swalwell, 2003). While cybercafés (or LAN cafés) initially provided places for players to link computers physically in order to play multiplayer games with speedier internet access, their popularity has not decreased with the onset of cable modems in many homes (Swalwell, 2003). Ethnographic studies in Australia, Asia, and Europe have identified reasons for this continued frequenting of cybercafés, namely the informal learning and dynamic social interactions present in such spaces (Beavis, Nixon, & Atkinson, 2005; Jansz & Martens, 2005; Lægran & Stewart, 2003; Swalwell, 2003). Most if not all of the informal learning cited by cybercafé players is directly related to the physical presence of other players in the same space and includes walking around and watching other people play, checking out the patches and new computer code others have downloaded for a game, asking about adjustments to computers, and watching their strategies in various games (Beavis, Nixon, & Atkinson, 2005).

More recently, researchers have argued that the boundaries between play in the virtual and the real are not as distinct as some have made them out to be, and both need to be considered as integrated aspects of play in virtual communities (Castronova, 2005; Jenkins, 2006; Kafai, in press; Leander & McKim, 2003). As Leander and McKim (2003) point out, experiences in cyberspace have become a part of the everyday activities and meaning-making of many adolescents and in fact often "extend rather than replace offline relationships" (p. 219). Indeed, thinking of either physical/offline/real or digital/online/virtual as self-contained denies their flexibility and the ways that people negotiate performance, meaning, and embodiment within them: "Only when we really acknowledge these spaces as legitimate and powerful sites of production, and acknowledge the diverse agents involved in their creation, can we begin to address the challenges facing them progressively" (Taylor, 2006).

Connective ethnography (Hine, 2000; Leander & McKim, 2003) is one methodology that has been proposed to address this issue of integrating research across online and offline spaces by "tracing the flows of objects, texts, and bodies" and analyzing the construction of boundaries within and between virtual and physical spaces (Leander & McKim, 2003, p. 211). Still in its nascent development it seeks to interrupt the artificial boundaries between online and offline spaces and understand "the processes by which social spaces are held apart and blended, and how boundaries and blends are recognized in everyday practice" (p. 229).

One of the reasons researchers have been so interested in studying gaming communities is because of the intricacies of game play. As Steinkuehler argues, participating in such communities is "cognitively complex and consequential" (2006, p. 50). In addition, many of them sponsor the development of distributed expertise and leaders who act as resources across the communities (Gee, 2004). This type of peer mentorship and development of expertise has been documented amongst children learning in online programming environments (Bruckman, 2000) and learning by design (Ching & Kafai, in press). Other researchers have noted the way that knowledge can spread (Roth, 1996) and even "snowball" (Anderson et al., 2001) amongst children sharing the same physical space in a classroom. What happens when children share not only a physical space but also participate in a dramatically larger virtual community?

In this study our goal is to conduct a connective ethnography that focuses on how gaming expertise spreads across a network of youth at an after-school club that simultaneously participates in a multi-player virtual world. We draw on multiple sources of information: observations (field notes), interviews, video recordings, online tracking and chat data, and hundreds of hours of play on Whyville ourselves. These different, complementary data sources embody the multi-modal aspects of connective ethnography, and allow us to trace players' activities and learning across physical and virtual spaces. Since this type of methodology is relatively new, we hope that this study will inform future efforts at researching and analyzing play and learning across blurred virtual and physical spaces.

While there are many different types of insider expertise that developed and became distributed amongst the youth of the club, in this first study we focus on one particular type of knowledge called teleporting and how it spread among club members. Teleporting consists of a simple two-word command typed in a player's chat that automatically transports players to social places unlisted in the destination menu on Whyville (e.g. "teleport moon" takes a player to a space in Whyville called the Moon not accessible in any other manner). The reason for focusing on this knowledge (teleporting) is threefold. First, it is a type of insider knowledge and a archetype of many facets of gaming capital (Consalvo, in press) discovered through personal trial and error or interaction with others. Second, it is a very traceable type of knowledge, easily identified in chat lines (though not visible to other players), and a common practice at the club that could not be learned outside of Whyville. Further, teleporting involves crossing different boundaries that are important to connective ethnography; not only does teleporting facilitate crossing between virtual spaces on Whyville, it represents passing between outsider and insider status in both the physically and virtually located communities of our study.

Research Setting and Approach

Whyville.net is a multi-user virtual environment (MUVE) with over 1.5 million registered players that encourages youth ages 8-16 to play casual science games in order to earn a virtual salary (in 'clams'), which youth can then spend on buying and designing parts for their avatars (virtual characters), projectiles to throw at other users, and other goods. The general consensus among Whyvillians (the citizens of the virtual community of Whyville) is that earning a good salary and thus procuring a large number of clams to spend on face parts or other goods is essential for fully participating in the Whyville community (Kafai & Giang, in press). Social interactions with others are the highlight for most Whyvillians and consist primarily of ymailing (the Whyville version of email) and chatting on the site where users are visible to each other on the screen (see the picture of the Beach in Figure 1). A pull down menu offers a listing of over 30 different places to visit and hang out together on Whyville

Some of the more popular places in which to socialize are not visible to users in the menus available on the site: Earth, Moon, Mars, Jupiter, Saturn, and the Newspaper. These sites can only be reached by "teleporting," which is done by typing "teleport moon" (or "teleport [place]") in the chat bubble above one's head. Since teleporting cannot be observed on Whyville (users are zapped to the new location before others have a chance to read what they typed), the existence of these locations and the knowledge of how to get there can only be discovered through conversation with other people or by visiting one of the few cheat sites that has tips for Whyvillians. Because of this, these select places come to represent insider status and many players prize them as social hang-outs because they are not over-crowded or over-populated by newbies.

Figure 1: Destination Menu, Teleporting to the Moon from the Beach, the Moon

In early 2005 we set up an after-school club where 20 youth in the 4th-6th grades came to play on Whyville for an hour most days after school. Most youth were new to Whyville, though one had played for the year before the club started. They distributed themselves among 10 computers, often sharing a computer or wandering around the room talking to others. While the club began as a quiet place, it quickly became loud and lively as participants learned the site and began to shout advice to each other, arrange parties on Whyville, chat, throw virtual projectiles at one another, and critique each other's avatars (Kafai, in press). Often clusters of youth would form around one computer when something interesting happened on Whyville (see Figure 2).

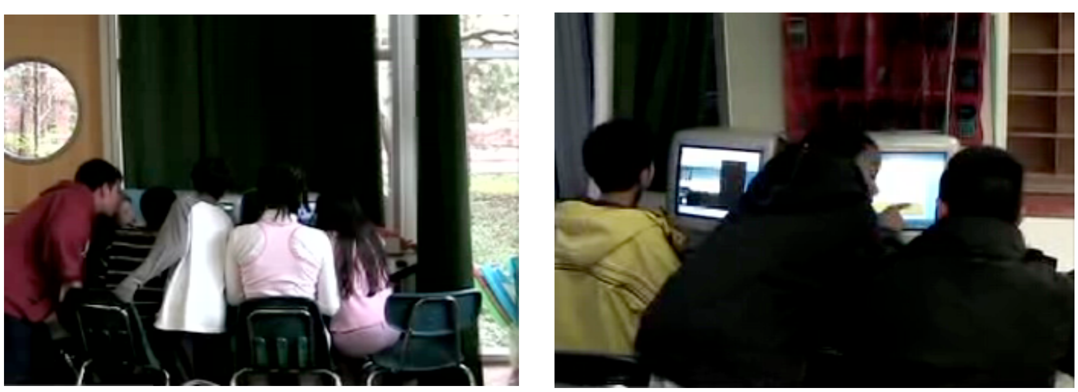
Figure 2: Club Members Clustered around Computers, One Member Helping Another

In order to study the children's activities in the "multiple, simultaneous space-time contexts" (Leander & McKim, 2003) of the club and Whyville, we gathered and analyzed numerous types of qualitative data aimed to track the youth in the club over multiple spaces (physically in the club as well as virtually over multiple spaces on Whyville). Ethnographic field notes were recorded daily to capture the overall activity of the club while video tapes focused on small groups of youth clustered at tables with 2-3 computers throughout the nine weeks the club took place in the winter of 2005. In addition, participants were interviewed individually at the end of the club and online tracking data including location and chat in Whyville was collected.

After an initial coding of the field notes and logging of the video data, we combed both types of data for any mention of teleporting or the places to which one can teleport. Whenever teleporting was mentioned in either source it was highlighted and/or transcribed. Similarly, the online tracking data was searched for the first time children teleported, and the first time they teleported to Saturn, since that place was not commonly known early in the club. This was done by selecting out club members' chat data from the larger database and searching for the times they typed "teleport" in their chat. This data allowed us to identify the first time each participant teleported, even if they were logged on to Whyville from home, and whether they sought any online help. After these incidents of teleporting were identified from all of the data, we organized them into a timeline to coordinate when and how children learned to teleport. We then further analyzed both the online tracking data and the video data to flesh out the context(s) in which children discovered that teleporting existed and was an option for them. Through this process we were able to compile a more complete picture of how and where youth learned to teleport than if we had not had each type of data.

Findings

There are many kinds of insider knowledge not obvious to newcomers in Whyville that were revealed in our own play and learning on Whyville, as well as our observations of club members in field notes, video, and chat. Among these are whispering, throwing projectiles, designing avatars, socializing, earning a large salary, and teleporting. Almost all of these activities involve multiple types of logistical and cultural knowledge. Some of these practices can be observed and copied: the chat syntax for throwing projectiles (done by typing "throw mudball [player's name]") is visible in other players' chat. Similarly, some flirting and befriending practices can be observed in people's chat unless they are whispering (a private conversation between two individuals). Avatars' looks can be copied, but it involves a very complex practice of earning clams (Whyville's currency), knowing where and how to shop and trade for face parts, and assembling a "good look" that will make certain types of people want to talk to you. Earning a salary is perhaps the most scaffolded of these practices on Whyville, since there are whole articles in the local newspaper (*Whyville Times*) offering suggestions. Still, playing the salary-raising science games and assembling face parts are not public on Whyville. They are carried out in spaces on Whyville only visible to the individual player.

Teleporting may be the least obvious insider knowledge since one cannot observe it in others' chat (the typed command "teleport moon" is not visible to others) unless people are publicly discussing a social gathering at one of the teleport locations. The only exception to this can be found on select cheat sites where instructions on teleporting are included on "tips" for newbies, or new players (Fields, 2007). Out of 39,673 lines of chat data from club members, 2372 (5.98%) were instances when the word teleport was used. By searching through this online chat data, we were able to determine when each club member first teleported (See Table 1). This formed the basis of further investigations into from whom, how, and where participants learned to teleport. The broad trend of teleporting activity reported in Table 1 reveals a few interesting things. For one, the first six youth to teleport (Kaitlyn to Aidan) were members of the two 6th grade classes where students were also starting to use Whyville and had more opportunities to play during the daytime than other club members. It seems natural that these would be among the first club members to learn to teleport.

Second, two weeks in particular, Jan. 24–30 and Jan. 31–Feb. 6, stand out as times when the largest numbers of club members learned how to teleport. What happened during those weeks? The identities and social affiliations of the club members give us some hints. The four boys who first teleported the week of Jan. 24 liked to throw projectiles together with Gabe, Aidan, and Kyle, so it is not surprising that they would learn fairly soon after their more advanced friends. The following week starting on Jan. 31 seems to be evidence of a snowball effect on the club (Anderson et al., 2001), as more youth learned to teleport, including three more girls. There is evidence in our field notes and video data that during the week of Jan. 31 teleporting and projectile throwing became a much more public activity, with youth yelling across the room to each other to "meet me at the Moon!" This probably allowed other youth to overhear their conversations. In addition, as more youth teleported, others could glance at their computer screens while wandering the room and see places like the Moon.

Table 1: Frequency of Typing "Teleport" Activities by Individuals over a Week.

Username	Name	First time teleporting	*Jan 4-9*	*Jan 10-16*	*Jan 17-23*	*Jan 24-30*	*Jan 31-Feb 6*	*Feb 7-13*	*Feb 14-20*	*Feb 21-27*	*Feb 28-Mar 3*
fairi60	Kaitlyn	*pre-club*	16	7	20	8	1	3	4		
whskr29	Briana	Jan 7	31	16	1		1				
WOW4	Gabe	Jan 7	1	7	2	6	3	1	1	5	
bluwave	Zoe	Jan 13		14	11	18	36	49	29	28	5
sharky404	Kyle	Jan 14		3	20	5	8		22	7	
masher47	Aidan	Jan 19			3	5	30	38	36	15	8
raybeams	Blake	Jan 24				20	10	14	48	5	13
stngray09	Trevor	Jan 24				1	7		20	19	
zink	Bryce	Jan 25				5		2			
leo95	Cole	Jan 28				14	9	4	13		
ivy06	Isabel	Jan 31					3		49	33	21
betelguice	Paolo	Feb 1					113	48	63	69	
vulcan61	Brad	Feb 2					16	9	25	11	14
sirius	Scott	Feb 2					8	18	17	8	5
amarylys	Jill	Feb 3					2		2		
Peachy5	Leslie	Feb 3					36	37	90	17	3
funster	Paul	Feb 8						52	27	40	11
Lucky7	Marissa	Feb 16							17	20	2
violet5	Ulani	Feb 16							9	4	
BluSwirls93	Molly	Mar 3									5
bloofer	Paige	Mar 24									
		Total teleport frequency	48	47	95	82	283	283	275	482	281

Upon a closer look, we found that club members learned to teleport in a variety of social contexts. Two among the first youth to teleport found out on Whyville by asking questions online (e.g. whskr29 and bluwave). This is perhaps the easiest learning method to identify since it is literally spelled out in the text (see Figure 3). Consider bluwave below, who on January 13 sought advice on a lot of things, including whispering, making friends, dancing, and teleporting:

ONLINE CHAT		INTERPRETATION
bluwave	i want to go to the moon	*First time she asks how to go to the Moon.*
...		
bluwave	how do you wisper to someone?	*Asks for help in whispering.*
bluwave	then what??	
...		
bluwave	do you like Whyville??	*Tries to make a friend, but performs a faux pax by asking for someone's real name.*
bluwave	what's your real name?	
bluwave	HOW?	
bluwave	what am I doing to bother you??	
bluwave	what's wrong with talking to someone??..I am just trying to be your friend	*Is criticized for her newbie look, probably created of cheap or free face parts.*
bluwave	you don't have to be mean just because I am ugly	
...		*Asks for help to stop dancing.*
bluwave	stop dancing	

bluwave	how do you stop dancing?	*Asks how to get to the Moon.*
...		*Probably told to type it.*
bluwave	do you knw how to get to the moon?	
bluwave	HOW??	*Types it incorrectly – probably corrected by a*
bluwave	ok	*helpful Whyvillian.*
bluwave	wanna go??	*Types it correctly.*
bluwave	transpertation moon	
bluwave	teleport moon	

Figure 3: Online Transcript of January 13: Sparkle 59 Learns to Go to the Moon

We chose this example because it reveals how teleporting is one of a number of things new Whyvillians learn. In addition, bluwave, like many of the club members, did not ask how to teleport but how to get to the moon. She tried asking anonymous people several times before getting the answers she needed. Unfortunately, the online data do not show us how bluwave first heard about the Moon. However, there are other cases where we have more information.

Instead of learning solely on Whyville, some club members learned how to teleport solely in the club by directly asking a club members. For instance, Gabe learned from Briana (whskr29, one of the earliest teleporters) while they were working on separate computers side by side (see Figure 4).

VIDEO TRANSCRIPT		INTERPRETATION
Briana:	Teleport to the moon!	
Gabe:	Okay, I don't know how to though.	*Briana tells Gabe to go to the Moon.*
Briana:	No no wait, hold on.	
Gabe:	You teleport me there, please.	*Gabe asks her to just type it in on his computer since he doesn't know how.*
Briana:	Just write Hey Marv.	
Gabe:	Hi- how do you spell Marv. *((typing "Hi"))*	
Briana:	M-a-r-v-, just write a he doesn't care. *((Gabe types))*	*Instead of answering, Briana recognizes another school friend, and tells Gabe to say hi.*
Briana:	No you didn't do r.	
Briana:	M-a-v enter	
Gabe:	Enter. *((laughs as he presses "Enter"))*	*Gabe types a greeting to Marv.*
...		
Gabe:	"Let's go to the moon." *((reading))* Okay. *((Gabe types a response))*	*Marv tells him to go to the Moon. Gabe responds that he will.*
Gabe:	Hey how do you teleport to the moon.	*Gabe realizes he doesn't know how to get there and asks for help.*
Briana:	Write, write that. Teleport moon.	
Gabe:	Okay.	
Gabe:	Tel-e-port *((typing as he talks))*	
Briana:	Don't write "to" just write "teleport moon," m-o-o-n *((spelling Moon))*	*Briana identifies an error in Gabe's command and corrects it.*
Gabe:	Teleport moon. *((types))*	*Gabe successfully goes to the Moon.*

Figure 4: Video Transcript of January 7: Gabe Learns how to Teleport

It is interesting that Gabe learned to teleport in the context of a social need to meet his friend Marv, a classmate who did not participate in the after-school club. In addition, since he was sitting next to Briana, she was able to observe him typing and corrected his initial mistake of typing "teleport to moon," a mistake that she made frequently when she learned how to teleport on Whyvlle earlier that day.

Yet while some youth were relatively easy to trace in terms of learning how to teleport, others were more difficult to trace in that they appeared to learn in both the club and Whyville, and even in Whyville learned from either or both club members and Whyvillians in general. For instance, on Jan. 31, the video data show that Blake yelled across the room to Cole, telling him to meet him at the Moon. While it is apparent from the field notes that Cole was in the room with Isabel and logged on to her computer not long after Blake's call, the online tracking data show that Isabel (ivy06) teleported to the moon directly after Blake called to Cole, then gossiped to someone on Whyville that Cole (leo95) was "hot." The table below is a shortened version of the event that shows what we were able to glean about the incident from the three primary types of data (see Table 2).

Table 2: Connecting Data Sources for January 31

FIELD NOTES	VIDEO DATA	ONLINE CHAT RECORDS	INTERPRETATION
~3:45pm Cole visits with Isabel, telling her about a girl who sent him a ymail. He types the girl's username on Isabel's computer so she can what the girl looks like.			*Cole is at Isabel's computer showing her a girl he had flirted with.*
	Blake: Cole! Meet me at the Moon!"		*Blake urgently tells Cole to go to the Moon,*
	Cole: Hang on! *((far away))*:	4:01:32pm ivy06 teleport moon	*Cole types in "teleport moon" on Isabel's computer.*
		4:02:38pm ivy06 leo95 says that u are hott	*Isabel sees the girl Cole pointed out earlier and whispers to her.*
~4:00pm Cole asks Isabel to log off so he can use the computer			*Isabel logs off and Cole logs on to her computer*

This incident explains Isabel's effort to learn how to teleport on the following day. It seems apparent that Cole either gave her direct instructions or typed "teleport moon" on her computer while she was logged on because the next day during club she tried to teleport but did it incorrectly a number of times and asked Whyvillians several times how to get to the Moon (see Figure 5).

ivy06	15:13:24pm	chat	go to moon
ivy06	15:13:42pm	whisper	do u now how to go to the moon?
ivy06	15:14:09pm	whisper	how?
ivy06	15:14:48pm	chat	teleport mars
.			
ivy06	15:15:42pm	chat	teleoport moon
ivy06	15:16:13pm	chat	teleoport moon
...			
ivy06	15:17:01pm	whisper	no how to go to moon?
..			
ivy06	15:24:06pm	whisper	how do u go to the moon?

Figure 5: Online Transcript of February 1: Isabel Tries to Teleport

Isabel eventually learned how to teleport consistently to Mars and the Moon, because on the following dates her tracking data show a typical club member pattern of teleporting from one location to the next in rapid succession (teleport Mars, teleport Moon, teleport Earth) while on Whyville. Interestingly, while Isabel saw the Moon and chatted with someone there on Jan. 31, in her interview, she said that she learned how to teleport from people at Whyville. Other members of the club received mixed instruction on teleporting from youth physically present in the club and from club members virtually present on Whyville.

The difficulty of tracing teleporting throughout the club is further complicated by participants often learning to teleport to one or two locations (generally the Moon and Mars) first and later adding to their knowledge through the discovery of other locations, like Saturn. Often this was done by trial and error or by knowing other planet names. For instance, on the same day that Cole first teleported, he also experimented with teleporting to a number of locations in the solar system, some of which existed, and some of which did not. Through this process, he discovered Saturn as yet another social location on Whyville (see Figure 6).

leo95	15:13:52	chat	teleport moon
leo95	15:14:22	chat	teleport Pluto
leo95	15:14:31	chat	teleport mars
leo95	15:15:04	chat	teleport Uranus
leo95	15:15:12	chat	teleport venus
leo95	15:15:33	chat	teleport sun
leo95	15:16:11	chat	teleport saturn

Figure 6. Online Transcript of January 28: Leo95 Discovers Saturn

Others discovered Saturn in an unusual club-wide social incident on February 16th. On this day, Leslie, who had learned about Saturn through experimentation (like Cole) a few days earlier, organized a get-together with Marissa, Ulani, and Isabel on that planet, inviting them by ymail to meet her at Saturn. This invitation seems to have provided the instigation for Marissa and Ulani to teleport for the first time, and while Isabel knew how to teleport to the Moon, Mars, and Earth, she had not been to Saturn before that day. While at Saturn, a Whyvillian not a part of the club insulted Ulani, who yelled out to the club that someone had insulted her on Saturn. Immediately several other club members teleported to Saturn, two for the first time (they had to ask how to spell it), and threw projectiles at the offender. By the end of the day, almost all of the club members had been to Saturn, doubling the daily average of Saturn visits by club members, a trend that continued through the remainder of the week.

Despite the many different ways that club members learned how to teleport, interviews revealed a decided preference for learning from other friends in the room (whether physically or virtually). Almost two-thirds (64%) of the youth interviewed said that the best way to learn something on Whyville was by talking to someone in the same room. The remaining youth preferred to talk to someone on Whyville. Specifically regarding teleporting, all but three of the youth interviewed reported learning from a friend in the club.

Discussion

Our study focused on how teleporting, a type of gaming expertise, spread across a network of youth at an after-school club that simultaneously participated in a multi-player virtual world. From our data it is clear that this particular type of information was only known to one member at the beginning of the after-school club and six weeks later it had spread to all but one of its members. The main mechanism we observed was a type of peer pedagogy (Ching & Kafai, in press) provided online and offline. By peer pedagogy we mean to describe the informal strategies of teaching others employed by teens. In addition to the direct mentoring found by Ching and Kafai (in press), overhearing others and wandering the room observing people's screens and activities planted seeds of curiosity about teleporting that were followed up on later. In a sense, it allowed for learning things that one did not know enough to ask about. Similarly, unplanned social activities served as instigators for learning; teleporting served an innately social purpose by providing transportation to places for people to hang out, and in turn social gatherings were big motivators for people to learn how to teleport. We also found that these opportunities for learning about insider knowledge were present online, perhaps most prominent in the anonymous asking often documented in the tracking data. It was a quick and easy way to get information from more than one person. It is perhaps this feature of information sharing and requesting which makes online gaming a fruitful learning environment as some researchers have argued (Gee, 2003). For those who want to learn, they develop strategies online and offline to request and receive help from others. For those who want to provide assistance, it is a good way to showcase their understanding. The motivations for such helping, ranging from altruistic to self serving are not always clear and require further investigations.

Studying interactions between online and offline gaming contexts presents considerable methodological challenges and requires new approaches as some researchers have argued (Hine, 2000; Leander & McKim, 2003), particularly because of the dynamic nature of interactions across spaces. The after-school setting in our study added another layer of complexity because movements, interactions and play among club members were not constrained in a specific space or time. Our observations indicate that the teens engaged in many of the interactions around gaming observed in adult commercial cybercafés (e.g., Beavis, Nixon, & Atkinson, 2005). In our analyses we found that each data source on its own presented us with an important slice of information about players' movements and purposes but no data source alone was complete. While the tracking data provided us with an accurate account of where players were going and what they were chatting about, it was often hard to discern why members did what they did. At times we also realized that the player logged in was not the player performing in Whyville as in Isabel's case; the tracking data alone would never reveal such information. The observational data provided both context and detail to players' interactions. The talk and movements captured in video and field notes often revealed how and why players decided to meet at certain locations and thus initiated learning about teleporting. The exit interviews confirmed the role of others as support in learning about new features in online gaming.

In what we would like to call 'multi-streaming' the different data sources, we were able to reconstruct and integrate a stream of complex interactions. In our particular case, we were also able to combine quantitative and qualitative data sources using online tracking logfiles and offline observational video and field note data. This allowed us to develop trajectories of how teleporting insider knowledge traveled through the player community. This was at first a gradual and then nearly exponential process through which all players (with one exception) became knowledgeable of this insider activity. We also needed to add to this stream of data our own player experiences that were an instrumental part in understanding what the club members were talking about in Whyville. While ethnographic analysis has always factored in the voice and role of the observer it is rarely complemented with logfile analysis.

Through this process of multi-streaming we were able to approximate one aspect of our research that is the seamless integration of online and offline interactions. For rhetorical purposes, we often use these distinctions to refer to different data sources but it was clear from our observations that our participants did not make these distinctions while being in Whyville. For them what happened online in Whyville was as much part of the same activity structure as what happened in the after-school club. Other researchers have for that reason started referring to synthetic worlds (Castronova, 2005) or as we have to synthetic play (Kafai, in press) to indicate the merging or synthesizing nature of online and offline worlds. This study demonstrates that research methodologies need to be adapted to match the complexities of interactions across the spaces of these worlds.

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Making Thinking Visible: Growth in Graphical Literacy, Grades 3 to 4

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Abstract: This study provides a new coding scheme to analyze growth in seven components of graphical literacy for 22 students who used an online multimedia environment--Knowledge Forum®--across two years (grades 3 and 4) to advance their theories in science and history. Students received no instruction in graphical literacy and were free to express their ideas in text or graphics. Results show increases in all components of graphical literacy over this time span.

Introduction

Graphical literacy refers to the ability to construct, produce, present, read and interpret charts, maps, graphs, and other visual presentations and graphical inscriptions (Readence, et al., 2004). It is a visual, abstract language for enhancing learning. According to dual-coding theory, information is easier to retain and retrieve when it is coded both verbally and visually (Paivio, 1991). Adding graphics to text can improve learning (Clark & Mayer, 2002), and visualization is also a powerful cognitive tool in scientific discovery and invention, and essential to problem solving in daily life as it provides concrete means to interpret abstract images (Rieber, 1995).

While there is a growing need for graphical/visual literacy, there is less attention paid to it at the elementary level than there is to reading and writing. There is evidence that higher order visual literacy skills do not develop unless they are identified and “taught” (Avgerinou & Ericson, 1997). Visual presentations of abstract concepts tend to be difficult for students yet ignored in basals and other school texts (Readence, et al., 2004). Educational researchers are calling for increased attention to graphical inscriptions to help students become literate in practices related to the production and interpretation of graphics (Roth, 2002).

Over the two years of educational work reported in this study students were engaged in knowledge building--the creation and continual improvement of ideas through transformative discourse (Scardamalia & Bereiter, 1994). Knowledge Forum, a knowledge building environment, was integral to their work. It includes tools for graphical as well as textual representation of ideas. Students choose the representational form best suited to the expression of their ideas. In knowledge building practices, students assume collective responsibility for communicating, elaborating, evaluating, and improving ideas, working in a public forum where they build on, comment, and in other ways help each other advance their understanding, They received no instruction in use of graphics, but are supported in the expression of ideas by peer feedback and an easy-to-use graphics palette that allows them to co-author and revise graphics. A coding scheme was designed to assess the extent to which they use graphics and advance in graphical expressiveness.

Method

Participants were 22 students from the Institute of Child Study, University of Toronto, using knowledge building pedagogy and Knowledge Forum software for their work in science and history. Quantitative results are reported and content analysis (Chi, 1997) was used to assess the quality of graphical content across grades 3 and 4. The coding scheme identified seven components of graphical literacy growth (Table 1); each graphical representation was rated for each dimension: Basic, 1 point; Intermediate, 2 points; Advanced, 3 points.

Table 1: Graphical Literacy Coding Scheme.

Category	Specification
1. Graphics Production/ Drawing Skills	Use of line, dot, shape, color, basic shape, etc; Combinations of different color, shape, label, title, etc.; Complex or abstract graphics conveying harmony, clarity in conceptual content, etc.
2. Graphical Representation	Use of a graphical representation to convey a concept, theory, experiment, procedure, etc.
3. Resources	Use of references and links to source material of peers or from the Internet to reference rather

Reference	than copy graphics.
4.Captions	Use of clear, correct, and accurate captions to complement and elaborate ideas in pictures.
5. Revision/ Elaboration	Revision or elaboration of pictures or relevant captions over time to provide increasingly clear and accurate accounts.
6. Aesthetics/ Clarity	Use of color, layer, rendering, etc. to make graphic attractive; effective use of titles, labels, tags, and other devices to create pictures that are reader-friendly and accurate.
7. Judgment/ Reflection	Use of interpretive comments and summaries to convey the essence of graphical representations, including processes conveyed by the picture.

Data analysis and results

Grade 3 students created 556 notes in total, with 68 graphical representations. In grade 4, students created 470 notes in total, with 123 graphical representations. The average number of graphical representations per student rose from 3.1 to 5.5, and the ratio of graphical representations to the total number of notes rose from 12.2% to 26%. All but one student used more graphical representations in grade 4 than in grade 3.

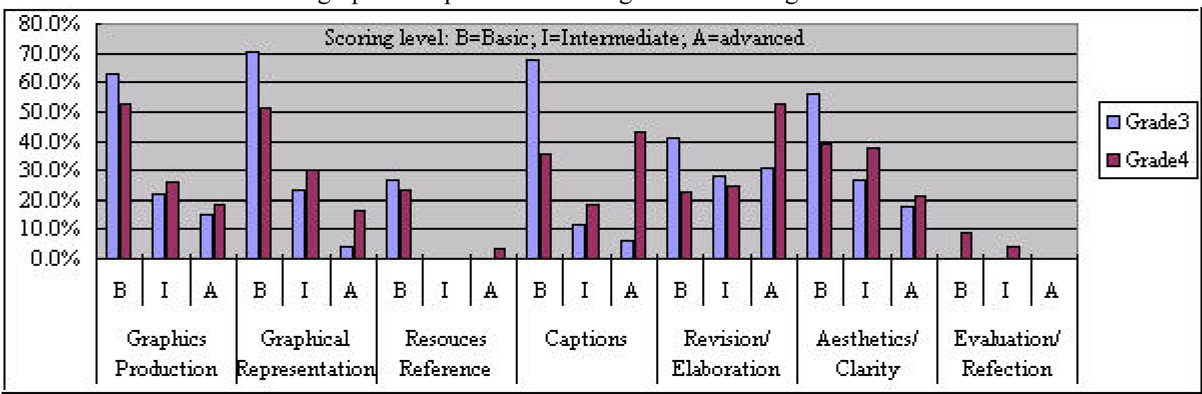

Figure 1. Rating of students' graphical representations in Grades 3 and 4.

Figure 1 shows the results of content analyses of students' graphical representations over the two school years (inter-rater reliability over 30 sampled graphical representations r=0.84, with differences resolved through discussion). The number of graphical representations rated as "Intermediate" and "Advanced" in six categories increased but one "Intermediate" level decreased in "Evaluation/reflection. The three areas of greatest increase in "Advanced" ratings were "Graphical representation", "Captions" and "Revision/elaboration," with corresponding decrease in the "Basic" levels in these same areas. There were no incidents of "Resources reference" and "Evaluation/reflection" in grade 3; but both appeared in grade 4. Paired *t*-tests of students' total scores in each category showed significant increases ($p<0.05$) between the two school years.

In the course of their knowledge building, students raised questions and worked together, as authors contributing notes to their collective space for shared understanding and as co-authors to continually improve ideas represented in their graphics. They also used "rise aboves," a note-type that allowed them to collect notes into an integrated, higher-order framework (see Figure 2).

Graphical representation, text and collaboration: The number of words per text note rose from 22.5 in grade 3 to 48.4 (doubled) in grade 4, and the number of words in captions, labels, and textual elements linked to graphics rose from 24.7 in grade 3 to 74.6 (tripled) in grade 4. These text elements were used to convey complex processes, experiments, models, and so forth, and in other ways elaborate abstract ideas conveyed in graphics. In grade 3, 17.6% of graphical representations were co-authored, and close to half (45.5%) of the students collaborated in the production of a graphical representation; in grade 4, the percentage is doubled (35.0%), and all but one student (n=21) co-authored graphical representations; suggesting that students had a stronger sense of collaboration surrounding their graphical work in grade 4.

Discussion

Quantitative and qualitative analyses of graphical representations showed increases in graphical literacy according to the coding scheme used to evaluate seven aspects of graphical literacy. A separate study by Zhang, et al., (in press) analyzed knowledge gains for the same students in the same class; these showed significant advances for individual students in their understanding of optics. Thus there is some suggestion that students use of text and graphics support content learning. Contributions of the current study include: (1) *Coding scheme.* Graphical literacy is seldom assessed in elementary schools and there are few studies to provide developmental accounts of graphical literacy. The current study provides a coding scheme that proved useful in assessing the work of students in grades 3 and 4 in an online learning environment; (2) *Literacy as a by-product of knowledge building.* Scardamalia (2003*)* proposed that knowledge building, with focus on conceptual advances related to core content, and conducted in a medium that requires multiple literacies for the expression and continual improvement of ideas, would result in increases in literacy, as a by-product of content learning. Previous studies (e.g. Sun, et al., under review) indicate this is the case for textual literacy. This study suggests that graphical literacy is another important by-product of knowledge building. A weakness of the current study is that there is no control data. Nonetheless, the study provides the basis for follow-up work aimed at assessing growth in graphical literacy, using both control data and assessments across a greater variety of classroom settings.

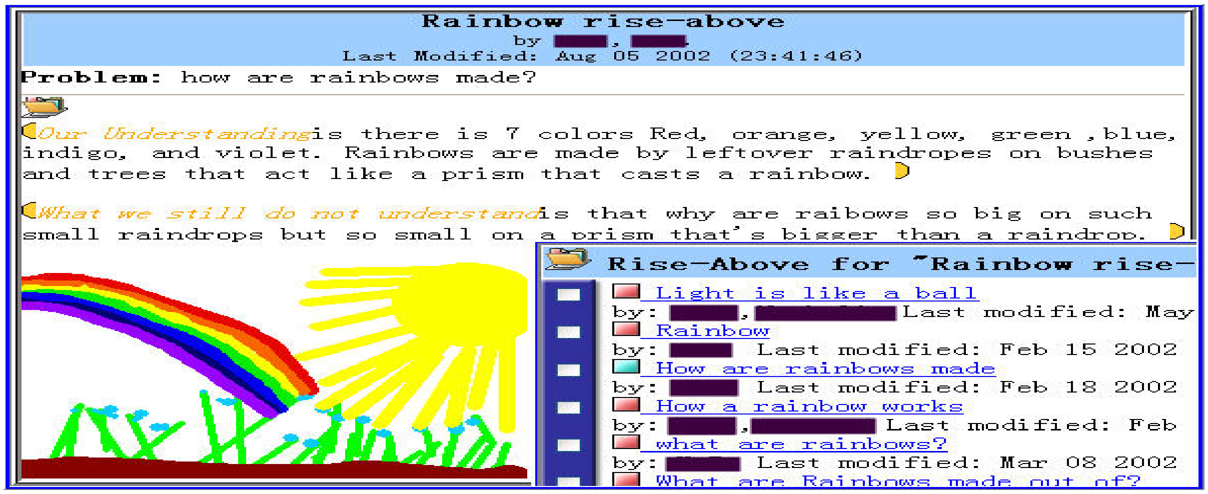

Figure 2. A rise-above note on "rainbows" in the "Colors of Light" view in Knowledge Forum.

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Turning on Minds with Computers in the Kitchen: Supporting Group Reflection in the Midst of Engaging in Hands-on Activities

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Abstract: How can we promote the kinds of reflection needed for deep and lasting learning and the development of disposition toward scientific reasoning in the context of an informal learning community? In our research, we've discovered that learners have a greater appreciation of what they are learning when we give them the goal of helping others outside their community. This appreciation is demonstrated by their willingness to jot down notes during activities and later write articles for an online cooking "magazine." The online cooking magazine has the potential to support learning and development of disposition toward scientific reasoning in several ways. It provides a place to hang scaffolding that promotes recognizing what's been learned, what led to successes, and how science contributed to those successes. It also provides a context for knowledge building in which learners create concrete artifacts they can share outside of the Kitchen Science Investigators community. We found that with computers in the kitchen and an online magazine to contribute to, participants were stopping and reflecting in ways that we had only seen previously when a facilitator was prompting them.

Introduction

How can we promote the kinds of reflection needed for deep and lasting learning and the development of disposition toward scientific reasoning in the context of an informal learning community? In busy learning environments where young learners are engaged in exciting hands-on learning activities, it is easy for them to energetically engage in activities but then walk away not recognizing what they learned (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). The problem is a cognitive one, but its solution will require some attention to pragmatics as well. Although it is hard to get children to stop, reflect, and articulate what they have been doing and learning while they are having a good time, finding ways to help learners do these things is important for fully realizing the affordances of problem, project, and design based activities. We'd like learners to come out of these learning environments having mastered targeted content, reasoning skills, and practices. In addition, we would like learners to have a disposition towards repeating the reasoning and practices they've learned (1). We seek to help learners develop dispositions toward engaging in targeted reasoning and subsequently carrying it out of their own free will. This happens only if learners recognize the usefulness and value of the reasoning they are doing (Bereiter, 1995) and have a chance to see that what they are learning has value within other social groups they participate in (Lave & Wenger, 1991). We do our work in the context of informal after-school activities.

In our Kitchen Science Investigators (KSI) project, fifth and sixth graders (ages 11 and 12) learn kitchen science and engage in scientific reasoning in the context of cooking and baking (Clegg, Gardner, Williams, & Kolodner, 2006). We are using KSI as a platform for learning to what extent we can promote disposition towards scientific reasoning through informal learning. We make available informal learning activities that learners choose to participate in out of interest. Then, we help them organize themselves as a learning community and recognize the systematic scientific reasoning they are doing in those activities that lead to success. Cooking and baking offer opportunities for learners to reason scientifically about process and procedure while developing skills for systematic inquiry as they iterate towards recipe perfection. Since many children this age and others in the community are interested in cooking and baking, participants are afforded many natural opportunities for sharing what they are learning in KSI with others in interdependent social groups (Barab & Duffy, 2000).

We believe that if we can systematically help participants see the value of their KSI experiences by helping them achieve and recognize some personal successes stemming from KSI activities through reflection, they will more readily engage in the kinds of reflection and articulation that will promote additional success. With cooking and baking, such success might come in the form of liking their own creations, having someone else like what they've prepared, offering tips to someone else who is cooking or baking, and engaging in "technical" conversation about cooking and baking with people whose opinions they respect. Our CSCL goal is fivefold: (1) understand how to use technology to prepare learners for such success; (2) give learners resources for engaging in activities and interactions that they feel have value outside of the informal learning community; (3) help learners recognize their successes and what went into them; (4) provide a platform for community knowledge building; and (5) help learners engage in interactions with others in interdependent communities.

During KSI sessions, participants work in small groups to achieve cooking and baking challenges (e.g., making pudding with the right thickness using various starch thickeners). In the first few sessions, participants work on the same cooking challenges. These challenges are designed to help them learn the science behind the cooking (e.g., how starches thicken) and to model processes for experimenting systematically (e.g., varying one ingredient at a time). Once the groups complete the challenges in their small group, they compare and contrast what they have done and discovered across all the KSI participants (Clegg et al., 2006). This allows them to see the effect that the ingredient under investigation has on the outcome of the recipe as it is varied and allows them to understand how it works. In the later sessions, they break into interest groups to pursue challenges of their own choosing – some variation or combination of what they've done previously -- using the science they've learned to achieve their goals (e.g., making pudding thick enough to support fruit in a pudding parfait).

In pilot studies of KSI, we have found that participants excitedly report their learning inside and outside of KSI. Between sessions some of them go home and share what they've been doing and many have had experiences where others get quite excited about what they've learned. We want to support those kinds of experiences for all participants, and we believe that this will require doing a better job of (1) supporting articulation of what they are doing and learning as they collaborate in their small groups and (2) providing opportunities for practicing expression of what they might share with others in order to show themselves and others the value of their KSI-related scientific reasoning. Our CSCL research question is this: *What roles can/should the computer play in an informal learning community to support the kinds of reflection that might lead towards the development of scientific reasoning dispositions?* We see CSCL having at least two purposes in promoting disposition towards engaging in systematic scientific reasoning: (1) supporting reflection while learners engage in activities that will lead them to recognize their successes and the ways they achieved them and (2) supporting articulation that will prepare participants for later conversations among their KSI peers and with others outside the KSI community. What they articulate during KSI can serve not simply as a practice opportunity, but if it is articulated in writing, it can also serve as something concrete to refer back to later when interacting with others.

Previously, we have used computers to support KSIers in annotating recipes with observations, and we have been disappointed that they didn't articulate more of what they were observing and learning (Gardner, Clegg, Williams, & Kolodner, 2006). However, we had not focused on giving them a reason to take notes and observations other than to perfect their recipes. In the study we report on in this paper, we gave them better reasons for reflecting, taking notes, and writing -- namely to share with and teach others about the science behind cooking. In particular, we made tools available to them for authoring an online cooking magazine that we hoped would provide them with enough structure and scaffolding to promote reflection and learning but not get in the way of their engagement and excitement. We found that with computers in the kitchen and an online magazine to contribute to, participants were stopping and reflecting as part of their finishing-up activities in ways that we had only seen previously when a facilitator was prompting them.

Design of the Software

We focused on four issues in the design of the software. (1) How can we support reflection in a context where learners don't want to leave the activity to write? (2) How can we support reflection without getting in the way of their activities and turning them off? (3) How can we use software to support groups' purposeful note-taking and written reflection? (4) How can we prepare participants for later conversations within and outside of the informal learning environment?

To begin answering these questions, we looked to our pilot studies in spring 2005 and 2006 (Clegg et al., 2006; Gardner et al., 2006). We saw that learners were excited about the things they were learning and that they wanted to share their recipes with and tell their stories to their friends and families both inside and outside of KSI. We wanted to take advantage of the opportunities afforded by that natural interest and excitement and hoped that they might periodically leave their activities to engage in jotting down those things that they wanted to share with others. The literature suggests that if we could have them reflect in a way that was authentic to their interests and to others outside of KSI, they would more readily think about what they where doing and what was worth writing down (e.g., Papert, 1991; Brown & Campione, 1990; Barab & Duffy, 2000). In addition, since learners, their parents, and their friends often asked for copies of their KSI recipes to take home, having a way for participants to access and share their recipes, stories, and advice online would help them reach an outside audience and give them an opportunity to see the social relevance of their KSI experiences.

We initially considered having learners author a cookbook, but because that medium limits contributions to recipes and annotated recipes, we decided against that approach and opted to have KSIers author a magazine instead. Cooking magazines have letters to the editor and requests for advice, stories, and how-to's in addition to recipes. Many of these match the types of interactions participants already have with their peers and adults when they talk about KSI. If we could support writing these things well in an online magazine, we could encourage productive kinds of reflection and scaffold that reflection for purposes that participants already wanted to engage in. The online magazine idea enabled us to achieve two objectives. First, it created a purpose for participants' reflection and articulation that was consistent with their excitement about sharing their discoveries and recipes. Second, it allowed for several kinds of writing products, each of which we could use as a platform for scaffolding. While one can think of many different ways of contributing to a cooking magazine, we began with three: (1) support for story writing (i.e., what I did and learned), (2) support for advice giving and explanations (using explanatoids from Crowley & Jacobs, 2002), and (3) support for recipe annotation. Figure 1 is a screenshot of the online cooking magazine homepage. The upper left quadrant features explanatoids written by the KSIers. The upper right quadrant features learners' KSI stories. In the bottom left quadrant learners can read advice column letters requesting cooking assistance (this is one way we suggest cooking and science goals to participants), and they can read the annotated recipes they and others have created in the bottom right quadrant of the page.

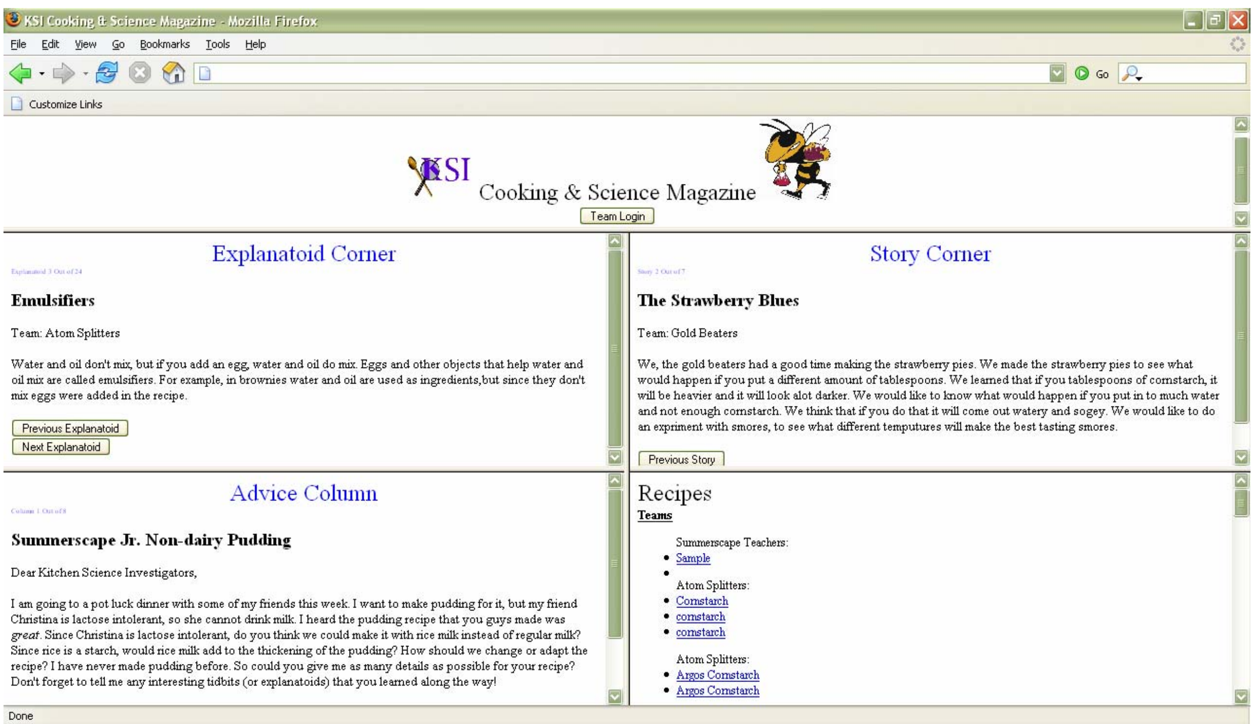

Figure 1. Cooking Magazine Homepage

In designing the reflection tools, we looked for direction on appropriate scaffolding for the type of learning we wanted to support. Both Scardamalia & Bereiter (1991) and McNeill, Lizotte, Krajcik, & Marx (2006) suggest allowing the environment to inform what type of support is necessary. We coupled this advice with our goal to support reflection without making it onerous and opted for a design with minimal scaffolding. While we knew we would find a need for additional scaffolding, beginning minimally would allow us to assess what scaffolding learners needed. We also adopted the Scardamalia and Bereiter (1991) usage of a community database to support knowledge building for the purposes of reaching a broader community and to provide a context for persistent group discussions. In KSI, small groups write entries together during activities, and refinement of ideas happens later when learners use their own entries and those of others as they address their own challenges that may occur either inside or outside of KSI. In designing the minimal scaffolding to help learners make their contributions to the cooking magazine, we used generic prompts (Davis, 2003) to remind learners to stop and think about what they are doing. We use more "directed" prompts only to focus reflection, particularly to help participants make connections between what they are experiencing and the science behind it. Overall, our prompts serve as suggestions to help participants articulate their experiences.

Story Telling Tool

The Story Telling Tool (Figure 2) was designed to allow KSIers to record their cooking experiences as stories. The scaffolding reminds them of the recipe they are working on and asks them to, "Tell us the story of your experience today in KSI." Scaffolding is in the form of five suggestions: "Tell us (1) what you did, (2) why you did it, (3) what you learned, (4) are there any unanswered questions from your experience, and (5) if there are any future experiments you would like to do as a response." The prompting is very simple, reminding learners to connect what they've done to what they can learn from it and suggesting that there may be more to learn. Overall, it provides a "model" of what we want children to think about, as, Collins, Brown, and Newman, (1989) suggest and Owensby and Kolodner (2004) demonstrate. The stories summarize their experiences so that they can use it as a resource when the KSI experience is no longer fresh on their minds.

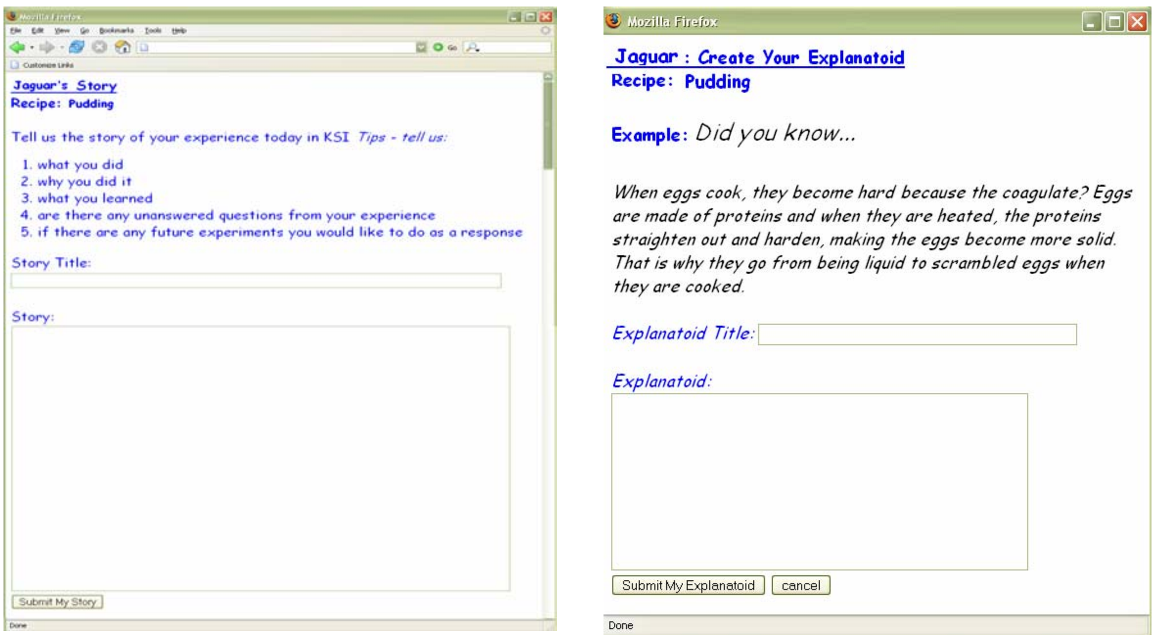

Figure 2. Story Telling Tool (Left) and Explanatoids Tool (right)

Explanatoids Tool

One KSIer's mom told us about an in-depth discussion her son had with his piano teacher about how yeast makes bread rise after he made pizza dough in KSI. The *Explanatoids Tool* (Figure 2*)* provides space for learners to record mini explanations about the things they are noticing, experiencing, and seeing to support these kinds of conversations. The generic prompt we chose for this tool was, "Did you know …" Our goal here was simply to prompt learners to make connections. We added an example of an explanatoid to provide additional guidance. Our goal here, as Crowley and Jacobs (2002) suggests about explanatoids, was to give learners freedom to explain at the depth they were capable of and wanted to express. The prompting in this tool is very generic, as it doesn't give specific instructions on what to write or how to write it. Davis (2003) reported that such simple suggestions promoted productive connection making, our goal for this tool.

The Recipe Annotation Tool

It is sometimes necessary to take notes while engaging in activities to remember enough to be able to reason or talk about them later. For this, we provided a Recipe Annotation Tool (not shown). In previous KSI implementations, we've had a hard time getting participants to make and write down observations. We conjectured that the goal of authoring articles in the cooking magazine might provide learners with more of a purpose for jotting down notes about their recipes so that they would remember later the things they wanted to include in their stories and explanations. Thus, we have renamed our old Cooking Observations Tool the *Recipe Annotation Tool*. The prompting we provide is simple structuring. Next to each step in a recipe there is space to type. After they finish preparing a recipe, participants can also upload pictures and add additional annotations.

Methods

Study Details

In summer 2006, we used this software in a week-long science summer camp with 60 rising fifth and sixth grade children from a variety of school districts around the metro Atlanta area. The summer camp was offered by a Georgia Tech K-12 outreach center as part of a summer science camp. Children were recommended by a teacher and had at least a B average. While participation in the study was free, children paid to participate in the camp. KSI was offered as the afternoon activity Monday through Wednesday and all day Thursday (15 hours total). Participants were split across three different rooms, 20 KSIers in each, all running in parallel. Within each room, learners were broken up into smaller groups of four or five to carry out investigations. Each room was facilitated by three local elementary and middle school teachers who we trained two weeks before. This implementation of KSI focused learners on the role of starch thickeners (e.g. cornstarch and instant tapioca) in making puddings and fruit pies.

Data Collection

Each group of five children had one laptop running the KSI software in a web browser. All entries in the software were recorded on a remote server. Database entries indicated the time each software entry was made, edits/updates to the entries and time those were made, and the group and activity they were associated with. We collected the entries made by participants in Rooms A and B. We also have video recordings of sessions and researcher field notes.

Data Analysis

We analyzed the software entries to find out the extent to which our ideas about using the cooking magazine and the authoring tools promoted reflection with respect to addressing the aforementioned four issues we considered when designing: (1) How can we support reflection in a context where learners don't want to leave the activity to write? (2) How can we support reflection without getting in the way of their activities and turning them off? (3) How can we use software to support groups' purposeful note-taking and written reflection? 4) How can we prepare participants for later conversations within and outside of the informal learning environment?

The data was analyzed for usage, number and quality of entries and edits, and who made them and when. Our goal was to gauge the extent to which the magazine promoted articulation (and the reflection that goes with it) and the content and quality of children's writing. Abundant usage might indicate that the tools were appropriately matched to learners' interests for sharing (design issues one and two). To address the third design issue, we looked at the types of things they wrote about and the quality of those writings with respect to the supports provided. For this part of the analysis we looked at the things they were motivated to write down and how they wrote them as indicators of the purposefulness of their reflection. The fourth issue was addressed indirectly through these analyses.

The analysis presented in this paper focuses on the usage of the Story Telling and Explanatoids tools, as they were the primary supports for making reflection more purposeful. We analyzed entries using a grounded-theory-like approach, allowing the data to inductively indicate its categories and patterns. In the next section, we present results from learners using both tools with respect to (1) usage (number of entries and edits made by who and when), (2) types of things written about, and (3) quality of content.

Results

Story Telling Tool: Usage

This tool was used during the last two sessions of the week. Usage was encouraged by facilitators prompting and encouraging the learners to write stories. For this tool, the data are from Room A, where a facilitator prompted use of this tool by bringing it up on each of the groups' computers. There were four stories written, one by each of the groups in Room A; one group edited their story.

Story Telling Tool: Types of Things Participants Wrote

All four entries in the Story Telling tool focused on making Strawberry Pie, which all the groups had just finished preparing. Three out of four groups used the tool to give recipe ingredients and steps. Two groups told the stories of their particular group experience making the strawberry pies in first person narrative. The other two groups told their stories as instruction, using the second-person pronoun "you". This suggested that learners had one of two goals when writing stories: *instructing* someone else or *describing their experience*.

Story Telling Tool: Quality of Stories

Table 1 shows examples of two stories KSIers wrote using the Story Telling Tool. Story S1 describes a group's experience and S3 gives instructions. Three out of four entries show groups usage of the prompts as scaffolds to structure the writing of the stories. One of the four entries was incomplete. It provided partial instructions for making the dish; we were unable to assess whether or not they would have used the prompts to structure the remainder of their writing. Three out of four of the entries included in the stories what the group did -- as suggested by the first prompt -- by writing the recipe's ingredients and steps. The other entry summarized the group's cooking experience in a single sentence. Three entries show that the groups identified the activity's learning goals. (e.g., "We made the strawberry pies to see what would happen if you put a different amount of tablespoons [of cornstarch]." "The Moon's did this to learn more about the science behind starches.") We believe that they did this because they took into consideration the second prompt, "Why you did it." These same groups built upon these responses by taking into consideration the third prompt, "What you learned." (e.g., "We learned that if you [add more] tablespoons of cornstarch, it will be heavier and it will look alot darker," "We learned that more starches thicken things more and make them better.")

Table 1: Examples of KSI Stories (2)

S.1 ***The Strawberry Blues*** We, the gold beaters had a good time making the strawberry pies. We made the strawberry pies to see what would happen if you put a different amount of tablespoons. We learned that if you tablespoons of cornstarch, it will be heavier and it will look alot darker. We would like to know what would happen if you put in to much water and not enough cornstarch. We think that if you do that it will come out watery and sogey. We would like to do an expriment with smores, to see what different temputures will make the best tasting smores.
S.3 ***The Moon's Strawberry Pie*** Strawberry pie isn't hard to make. All you need is 3tsp of cornstarch, 32 strawberries, half a cup of sugar, half a cup of water, and 6 graham cracker crusts. You will also need a potato masher, paper cups, saucepan, measuring cups and spoons, and 4 cup storage containers. Next you will have to place the strawberries in the saucepan, and mash them with the potato masher. It will look pretty nasty, but we'll see about that later. Stir your water with the strawberries. Put the saucepan on the over your burner (hopefully you'll have one)and put it on meedium heat, until the mixture begins to boil for about 5 minutes. In a seperate bowl, measure and mix your 3tsp of cornstarch until blended well. Once the strawberries come to a boil, sprinkle the cornstarch sugar mixture a little at a time, stirring after each sprinkle to make sure that it is well blended. Stir it until the mixture thickens. Then boil it for a minute and cool it for 10 minutes. Your last step is to take a 1/4 measuring cup and put it in each crust. Wala!! The Moon's did this to learn more about the science behind starches. We learned that more starches thicken things more and make them better. The Moon's want to do future experiments with cooking such as what happens when Mentos and Diet coke. We all hoope you enjoy your specail for today, enjoy!!

The two stories in Table 1 are complete with respect to what the prompts in the tool suggested they write; however, the stories are quite different. We think this is because the two groups had different goals. The group that wrote story S1 had the goal of describing their group's experience. Suggestions from prompts four and five fit very nicely into the telling of their strawberry pie-making experience. While it seems like they are posing an unrelated experiment in their last sentence, they are actually reflecting on the model/process of the science experiment they did in the previous session to perfect thickening their pudding. The group writing story S3, on the other hand, seemed to be writing instructions for someone else. In achieving their goal they did not have to take into consideration prompts 4 and 5, the unanswered questions and related experiment(s) prompts. Nevertheless, they included in their story an unrelated experiment that they were interested in pursuing.

Story telling seemed to come naturally and be quite enjoyable for some of the groups. Some groups personalized their entries with narrative flow, personal notes, humor, and "style" (e.g., "Next you will have to place the strawberries in the saucepan, and mash them with the potato masher. *It will look pretty nasty, but we'll see about that later*." + "Put the saucepan on the over your burner *(hopefully you'll have one)*" + "*Then...Wala!!*" and "*We all hoope you enjoy your specail for today, enjoy!!*"). Although this is a small sample set (4), the stories give us clues as to what participants were attending to and noticing while cooking. Furthermore, their varying goals suggest that in future software, it makes sense to better separate out story telling from instructing.

Explanatoids Tool: Usage

The Explanatoids tool was used during three sessions and by both rooms of children. Participants wrote 20 entries total, with the bulk coming from Room B. In room B, the average number of entries per group was 4.5, and each group made an average of 2 edits each (Table 2). Edits of their writing suggest that they had some investment in it.

Table 2: Usage of Explanatoids Tools

By Whom	# of Entries	Edits	When (# of Entries created)
Group B1	7	3 (edited 3 diff. entries)	Session 2 (1), Session 3 (edit) Session 4 (6)
Group B2	5	None	Session 2 (1), Session 4
Group B3	3	2 (edited 1 entry twice)	Session 2 (1), Session 4
Group B4	2	1	Session 2 (1), Session 4
Group B?	1	None	
Group A1	1	None	Session 4
Group A?	1	None	Session 4

Explanatoids Tool: What Learners Wrote

A grounded theory-like analysis of these writings showed groups writing with one of three primary goals: expression, informing, or explaining. We define *expression* as *making known one's opinions or feelings* (e.g., "today we made chocolate tapioca pudding and the teachers and other people older than us liked it. we made it with corn starch too, it tasted really good."). Two entries out of twenty were coded as "expression". We define *informing* as *communication of procedure, data, and knowledge obtained from investigation, study, or instruction* (e.g., "We heated cornstarch and water, to see how long it took to thicken. It took about 10 min. to start thickening. We knew it was thick when it started to stick to the back of the metal spoon. Every 5 min. the temperature seemed to rise about 10 degrees."). Thirteen out of twenty entries were coded as "informing". We define *explaining* as *providing a reason for the occurrence of something beyond one's personal experience* (e.g., "After a long time of stirring and cooking, the pudding thickened because of the arrowroot. The starch in arrowroot thickened because the starch sucked up the water and swelled up."). Five entries out of twenty were coded as "explaining".

Explanatoids Tool: Quality of Explanations

We coded each of the explanatoids for the presence and quality of explanations (attempts to use science rather than just descriptions of experience), identifying for each the presence of cause, mechanism, and/or why the phenomenon they are presenting is important. *Cause*, as we use it, is *the reason for the phenomenon being explained* (e.g. "because when you add water to a starch,it becomes thicker," and "Eggs and other objects that help water and oil mix are called emulsifiers"). See Table 3 for the full text of the explanatoid entries. *Mechanism* is *the underlying process responsible for a phenomenon* (e.g., "this kind of starch does like water, so it absorbs the water"). We coded entries for having identified *why the phenomenon was important* when they included *contextualized examples of the phenomenon or other discussion of the phenomenon's importance and relevance* (e.g., "For example, in brownies water and oil are used as ingredients, but since they don't mix eggs were added in the recipe.").

Table 3: Examples of Explanatoid Entries

Pudding	"The brown rice flour thickened when we stirred it because when you add water to a starch,it becomes thicker and this kind of starch does like water, so it absorbs the water."
Emulsifiers	"Water and oil don't mix, but if you add an egg, water and oil do mix. Eggs and other objects that help water and oil mix are called emulsifiers. For example, in brownies water and oil are used as ingredients,but since they don't mix eggs were added in the recipe,"

Nine out of the twenty entries had content that was coded as a cause. Two out of twenty entries had content that was coded as a mechanism. Three out of twenty entries had content that was coded as the reason why a phenomenon was important. Several categories of explanations emerged from these codes: (A) Description of a Phenomenon (effect), (B) Description of a Phenomenon (effect) + its importance, (C) Description of a Phenomenon (effect) + why (cause), (D) Description of a Phenomenon (effect) + why (cause) + how (mechanism). The majority of entries were of types (A) Description of a Phenomenon (effect) and (B) Description of a Phenomenon (effect) + why (cause). Table 4 shows a breakdown of the number of entries coded in each category and its definition. Of the 20 entries, 12 had some sort of explanation, while eight simply described something they observed.

Table 4: Four Categories of Entries in the Explanatoids Tool

Explanation Type	Description	# of coded entries
a) Description of phenomena (effect)	Describes an observable effect of the cooking process	8
b) Description of phenomena (effect) + its importance	Describes an observable effect of the cooking process and adds information about why it is important	3
c) Description of phenomena (effect) + why (cause)	Describes an observable effect of the cooking process and why it was caused	7
d) Description of phenomena (effect) + why (cause) + how (mechanism)	Describes an observable effect of the cooking process, why it was caused, and the mechanism of how it was caused	2

In discerning the quality of the entries, we looked for attempts to use science. We identified five uses of science in 12 out of 20 entries. Table 5 illustrates examples of each and their usage, noting in bold type the part that was coded and in italics our clarifying notes.

Table 5: Examples of Attempts to Use Science

Quality of Science	Entry (Example in bold and notes in italics)	Overall usage
(1) Definitions	Water and oil don't mix, but if you add an egg, water and oil do mix. **Eggs and other objects that help water and oil mix are called emulsifiers.** For example, in brownies water and oil are used as ingredients, but since they don't mix eggs were added in the recipe.	1
(2) Attempt at qualifying an opinion by science	**Out of the 4 brownies #2 was the best** *(opinion)* **because it had the right amount of eggs** *(science)*.It also had the most flavor and the most greasy.	1
(3) Experienced science (cause & effect)	Water and Oil don't mix. The eggs mixed the water and the oil. **The brownies became bigger** *(effect)* **when more eggs were added** *(science cause)*. The first brownie was the smallest because only one egg was added.	4
(4) Use of science to explain the cause	After a long time of stirring and cooking, **the pudding thickened because of the arrowroot** *(4)*. **The starch in arrowroot thickened because the starch sucked up the water and and swelled up.** *(5)*	3
(5) Use of science to explain the mechanism		2

From this data, we see that participants composed explanations at varying degrees of specificity, and some didn't explain at all but only wrote observations. Nine out of 12 entries that were coded as explanations were written by three out of the five groups. We also see that most of the groups were able to articulate at least the cause and effect of phenomenon they experienced through program activities, and some were able to use the science to describe the cause and the mechanism.

Discussion

While this research study had a very small data set, it was interesting nonetheless because the study participants actually stopped to write, and the writing shows they are learning more than we originally thought. This is especially interesting because in the past we found it difficult to get learners to reflect during activities and even sometimes after they finished. When we did get them to reflect and articulate, they rarely revisited notes or refined them over time. The usage analysis presented here suggests that the cooking magazine and its authoring tools provided a successful medium for promoting reflection and articulation. Not only did participants record some of what they learned, but they sometimes took the time to revisit what they wrote. Edits included revising mistakes in science understanding and adding more relevant details as they emerged in the learning environment. The recording and editing practices from this study also suggest that providing authoring tools with authentic purpose elicited group reflection. In addition, the length of the stories and quantity and length of the explanation entries suggest that learners will invest time into such authoring if they value the purpose of the writing. Though not presented here and not yet analyzed at depth, we also saw that learners made far more notes while cooking (using the Recipe Annotation tool), further suggesting that participants valued the authoring they were doing.

In analysis of what participants were motivated to write down, we see that learners were capable of doing the type of reflection we think is necessary for later sharing. We also see that they needed help with consistently linking the science they are learning to what they are doing and articulating that science. Learners told stories about their experiences -- adding in observations, personal comments and opinions, and questions about issues they wanted to learn more about. They were even motivated to begin devising experiments to find answers to those questions. While these results don't suggest that they had arrived at the point of recognizing relevance, they do suggest that they were doing the reflecting necessary for a disposition toward scientific reasoning to develop.

We want participants to use the science they are learning and recipes they've created at home with friends and family. To use the science, they need to have recognized that they know it and have enough understanding to try to use it. Our results show many learners identifying the science they were learning from the KSI activities and using it in explanations they wrote. Most groups were able to write about the cause and effect of phenomena they experienced, similar to what we have seen in the past. Our results exceeded past performance in the quality of the science included in their writing and the subsequent connections they made between their experience and the science. These results resemble the quality of science talk we observed previously only when a facilitator was engaging a group in conversation and helping them relate their experiences to the science behind it. We are happy to find that artifacts of these conversations were recorded with the tools and that learners were engaging in this type of reflection in their small groups without the presence of a facilitator.

Between the two tools, we saw that learners had different goals (e.g., giving details about or describing their experience, instructing, informing, and explaining) that seemed to affect their ability to connect the things they were experiencing to the science behind it. Our results also seem to show a relationship between the goals and the prompts we provided. When the prompts built upon one another, the groups that had goals of telling the story of their experience were able to use the prompts to weave a story together naturally (two groups out of four). On the other hand, the group that had the goal of instructing was able to see the value in what they had done but were not motivated to wonder about what the prompts were suggesting. This may be due to the fact that thinking about unanswered questions does not naturally follow the goal of giving advice to others. Davis (2003) reported that this is one of the downfalls of using directed prompts, as some children have difficulty understanding what the prompts are asking for and subsequently just choose not to respond or flounder in their answers. In this case, we think they had problems with the prompts because they were writing something different than what the authoring tool they chose was intended for. We will need to identify the range of authoring tools that are needed and scaffolding that "flows" for each. In the Explanatoids Tool, where prompting was more generic, we saw more varied goals and expressions related to those goals, but not all entries were rich in science content. This suggests that the tool allowed learners the freedom to explain at a depth they were capable of and wanted to express. However, some groups might have produced better explanations with more directed scaffolding. We still need to better understand the tradeoffs and tensions in designing more and less directed scaffolding. It is important that scaffolding doesn't seem like school by making explanation-making seem onerous. On the other hand, we want to give learners help in expressing scientific connections as technically as they can.

Conclusion

Authoring articles for an online magazine was a good motivator for getting children to stop, reflect, and record. Why is this relevant to the CSCL community? In this KSI enactment, the computer played an important role in eliciting productive group reflection beyond what we have seen in past KSI implementations. Our results suggest that the kind of collaboration tools we provided helped participants ready themselves for productive interactions within and outside the community of learners they were engaging with, an important prerequisite to developing disposition. Analysis of the discussions learners were having within their small groups and as a learning community would tell us more about the actual effects of the authoring tools we provided and the authoring purpose we chose. Our next steps will include extending the software to include more support for interactions across and between communities, better scaffolding for explanations, and additional authoring tools. Our next studies will look not only at the potential of such authoring tools to promote learning and communication, but will also follow those interactions to show us other needs in developing tools for connecting interdependent communities and the extent to which such interactions are promoting productive science discussions and learning over time. Future studies will also look at the extent to which learners find value in the science they are learning and the scientific reasoning they are doing, and if learners are developing the dispositions we are targeting. These studies will help us address our fourth design question: How can we prepare participants for later conversations within and outside of the informal learning environment?

Endnotes

(1) For the purposes of this study, disposition toward scientific reasoning refers to taking initiative to connect evidence to claims and to connect mechanism to cause and effect relationships. More generally, we think of disposition toward scientific reasoning as taking initiative to participate in the whole range of practices scientists tend to practice inside and outside of their labs – asking questions, wanting to understand how and why things work, designing and running experiments, producing and using evidence, generating explanations, and so on.

(2) Text of learners' writing has been left unaltered, meaning no changes were made to spacing or grammar. However, where needed text was inserted in [brackets] to clarify the point of the text to reflect its context.

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Intuitive moderation styles and beliefs of teachers in CSCL-based argumentation

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Abstract: CSCL learning environments provide new contexts for discussions and are thought to provide new opportunities for learning. At the same time, such environments often do not provide guidance on how to act during the discussion. The purpose of this paper is to initiate research on moderation in synchronous discussions in a CSCL environment. The first study contrasts teachers' beliefs on good discussions and good moderation pertaining to face-to-face discussions with those pertaining to synchronous, CSCL-mediated discussions. The second study focuses on the strategies teachers intuitively enact in synchronous discussions.

The challenge of moderation in CSCL-based argumentation

Learning processes in classrooms are influenced by the quality of discussions in which the teacher engages with the students, and particularly the teacher's moderation practices (Mercer, 1995; Chi, Siler, Jeong, Yamauchi & Hausmann, 2001; Wegerif, 1996; Atzmon, Hershkowitz & Schwarz, 2006). Oral discussions are generally teacher-centered. The teacher raises questions, directs answers, stresses important issues, selects speakers, summarizes and presents new points into the conversation. CMC tools such as CSCL learning environments provide new contexts for discussions and are thought to provide new opportunities for learning: they enable learners to follow the developing interactions among others, to mutually examine the extent and nature of their own involvement in the process, and at the same time and to create awareness of the processes of self-thinking (Lave, 1991). At the same time, such environments rarely provide guidance or direction concerning how to act during the discussion (Soller, 2001).

Types of discussions in classrooms are varied. Among these types, collective argumentation is particularly important for learning purposes. The object of argumentation, the elaboration of arguments, has been recognized as central in knowledge acquisition (Driver, Newton, & Osborne, 2000; Schwarz, Neuman, Gil & Ilya, 2003; Zohar & Nemet, 2002), and epistemological understanding of knowledge construction (Duschl & Osborne, 2002; Erduran, Osborne, Simon, 2004; Sandoval & Reiser, 2004). However, several researchers have pointed at the difficulty teachers have at mediating collective argumentation. They need to continuously evaluate students' knowledge and to enact argumentative moves timely and adequately in order to promote understanding: asking for new perspectives, pointing at contradictions, inviting to participate, inviting to give explanations, etc. (Yackel, 2002; Schwarz, Dreyfus, Hershkowitz, & Hadas, 2004).

The complexity in sustaining argumentation has led scientists to elaborate CSCL tools for supporting collective argumentation in peer interaction. These tools (also called CSCA tools) have to be differentiated from knowledge representation tools (Bell, 1997; Van Bruggen, Kirschner, Jochems, 2002), since they support collective argumentation by affording argumentative moves to be taken by various speakers through discussion. The Digalo environment (Glassner & Schwarz, 2005) presents an approach that integrates these two models of fostering argumentation: the model emphasizing "knowledge representation", or "argument representation", and the supportive model in the argumentative process. Using this tool synchronously enables textual multiple-talk through which each of the subjects adds messages through mediation of graphical icons representing categories in collective argumentation and in argument construction (these categories are called the ontology of the environment). The underlying assumptions of the designers of this tool were that visual ongoing representation of the discussion can help students to reflect upon their argumentative steps and their components, and that discussants will enact practices of productive discussion (Glassner & Schwarz, 2005). And indeed, synchronized communication amongst subjects, mediated by ontologies characterizing collective argumentation (such as 'claim', 'argument', 'explanation', 'comment', 'question') as well as relational categories (such as 'support', 'opposition' or 'reference'), appeared to be productive (Glassner & Schwarz, 2005). In other words, adequate ontologies may have a mediating effect in the sense that when learners use the tools, they take more into consideration crucial features of collective argumentation, among them the reference to others as well as criticism and justification. The persistence of the argumentative map suggests the clear articulation of opinions, inspection of the map to decide whether the contribution is new, reflection to evaluate understanding of previous moves, and to possibly request additional explanations, etc. However, these suggestions have been empirically corroborated without considering the role of human moderation, a role that was recognized as crucial in the long run (Shahar, 2003; Hakkarainen, Lipponen, & Järvelä, in press). It is then imperious to focus on the role of human moderators in helping students while discussing with CSCL tools.

To begin with in this endeavor, we use the general term 'moderation' to designate any kind of support given by a human to help at reaching the goal of the e-discussion. Researchers used different terms such as 'scaffolding', or 'mediating' to delineate teaching actions aimed at supporting construction of knowledge. Since we adopt a bottom-up approach, we will use 'moderation' as a general term but we will preserve terms used by researchers Three types of mediations have been identified in CSCL literature for either synchronous or a-synchronous interactions (Ashton, Roberts, & Teles, 1999): *pedagogical scaffolding*; *social scaffolding*; and *technological scaffolding*. *Pedagogical scaffolding* refers to moves aimed at achieving predetermined learning goals in order to help the learner complete his/her assigned task **(**Mercer, 1995; Muukkonen, Hakkarainen & Lakkala, 1999; Wegerif, 1996). It includes positive reactions, instructions, providing information and opinions, advising, pointing out preferences, raising questions, and a summary of students' remarks concerning external sources. Various researchers adopted different strategies. For example, Chi and colleagues (Chi et al., 2001) proposed an approach according to which interaction between teacher and student can be planned by asking generic questions, such as: “Can you explain...”, or “Articulate it with your own words”, “What are you thinking about the issue?”, “Could you add anything about the subject?” (See also Baker and Lund, 1997, for a similar approach that yielded positive outcomes). While Wegerif (1996) proposes a similar approach with scaffoldings in the form of questions such as: "What are you thinking?", and "Why are you thinking that way?", his perspective is less cognitive than ethical and dialogical since he is eager to instill ethical norms of argumentation rather than to instigate dialectical processes. *Social scaffolding* refers to support based on empathy, humor, and personal assistance. *Technical scaffolding* includes technical support with the software and interface for students working in a CSCL environment. These and other kinds of distinctions concerning kinds of moderation were done either theoretically or by observing teaching practices. In this paper, we adopt a bottom-up approach as we both consider both beliefs and practices of teachers in a specific case – synchronous e-discussions, so as to distinguish between kinds of moderation in that case.

The nature of human moderation in synchronous e-discussions and its influence on the quality of such discussions are open questions. These questions are relevant to ARGUNAUT (IST-2005027728 – partially funded by the EC under the 6th Framework Program, http://www.argunaut.org), a project aimed at providing tools for supporting the moderation of synchronous e-discussions. The present paper represents an initial step in this program. First of all, we need to learn about teacher beliefs and practices concerning moderation of synchronous discussions. The first study contrasts teachers' beliefs concerning good discussions and good moderation in face-to-face discussions and in synchronous, CSCL-mediated discussions. The second study focuses on the actual strategies teachers intuitively enact in synchronous discussions. In the two studies, the populations were different. This was due to difficulties in recruiting and training teachers to be moderators in synchronous discussions. The results of the two studies suggest the elaboration of suitable awareness tools to help teachers in mediating CSCL discussions.

The Research questions

1. How do teachers characterize and describe what constitutes a good discussion in oral classroom settings, as opposed to discussions in CSCL-based argumentation?
2. How do teachers characterize and describe what constitutes good moderation of oral classroom discussions, as opposed to moderation of discussions in CSCL-based argumentation?
3. How do teachers actually moderate synchronous, collective argumentation?

Study 1: Teachers beliefs about good discussions and moderation of discussions

Participants

The questions were investigated in the framework of an in-service teachers program aimed at promoting dialogic thinking in classrooms. Ten teachers from two different high-schools participated in the study: seven (six women and one man) from the first school and three (two women and one man) from the second.

Procedure

Two questionnaires were administered, one before and one after teachers designed a Digalo-based learning activity and implemented this in their classroom. Before the implementation teachers were asked to answer the following questions: "What is in your view a good classroom discussion?" and "What is in your view a good moderation of classroom discussions?" Following the classroom implementation, they answered two additional questions, namely: "What is a good Digalo discussion?" and "What is good moderation of Digalo discussions?" The ten teachers from the two schools answered the first questionnaire. Due to technical problems, only the seven teachers from the first school answered the second questionnaire.

Table 1. **Relative frequency (in %) of different teacher response categories to the question: "What is a good discussion in classroom/Digalo?"**

Category		Classroom Discussion (n=10)	Digalo Discussion (n=7)
Social dimension	Participation	40%	57%
	Collaboration	0%	28%
	Interaction	40%	57%
Ground rules for discussion	Attention / listening	60%	0%
	Mannered verbal content	50%	14%
	Mannered turn-taking	50%	0%
	Preventing domination of specific pupils	20%	0%
	Quiet atmosphere	0%	14%
	Preventing students' "flight" (e.g. surfing internet)	0%	14%
Cognitive dimension	Task-focus and relevancy	60%	0%
	Relevancy to the topic	30%	0%
	Construction of knowledge	60%	0%
	Valid of Argument	60%	28%
	No repetition	10%	0%
	Students' interest	0%	14%
	Deep discussion (not superficial)	0%	14%
	Clear map structure - organization of nodes	0%	57%
	Clear map structure - coherent ontology	0%	57%

Table 1 demonstrates the differences in teacher beliefs concerning qualitative oral versus Digalo-based collective argumentation on the cognitive dimension: Most of the teachers mentioned that a good classroom discussion is focused on task and relevant to the topic proposed, leads to the construction of knowledge and is characterized by valid arguments. They did not indicate, however, these categories for a good Digalo discussion, except for the validity of the argument. On the other hand, teachers described good Digalo discussions as those in which students' interest is high, in which the maps that students created during the discussion seemed well organized and in which students made adequate use of the ontology proposed.

Table 2. **Relative frequency (in %) of teacher response categories to the question: "What is good scaffolding/moderation in classroom/Digalo discussions?"**

Category		Classroom Discussion (n=10)	Digalo Discussion (n=7)
Social dimension	Participation	20%	43%
	Discourse norms	100%	71%
	Interaction	30%	14%
Cognitive dimension	Eliciting more perspectives	20%	57%
	Focus	70%	28%
	Organization / construction of knowledge	60%	43%
	Posing challenges to students	30%	43%
	Increasing interest	20%	28%
	Asking for clarification	0%	43%
	Digital mediation of teacher	irrelevant	43%
	Correct use of ontology	irrelevant	14%
	Technological aspects	irrelevant	57%
	Learning design	0%	14%

Table 2 shows that for oral and Digalo discussions, good moderation means primarily mediation for participation, for adequate discourse norms and for interaction. Fulfilling norms of discourse was less important for digital discussions, though. In general, the criteria for quality of moderation in the two media were quite big. Concerning the cognitive dimensions, 'focus' which was so central in oral discussions was far less important in digital ones. Interestingly, a very different aspect, somehow orthogonal to 'focus', 'eliciting more perspectives' was considered as a good moderating action. Teachers also mentioned 'asking for clarifications' as central for digital discussions whereas this action was not mentioned as reflecting quality of mediation in oral discussion. Of course, 'technological aspects' did not appear for the oral discussion. These two categories did not appear in the teachers' answers when evaluating the moderation of oral discussions in classrooms.

In addition to written responses, teachers sometimes clarified what they meant. Many teachers stressed the importance of prerequisites for the success of any Digalo-based learning activity. They stressed the importance of investing a lot of effort and thought in (a) becoming well acquainted with the tool, (b) preparing and designing the sequence of activities, and (c) organizing social settings (e.g., assigning students to small groups based on their learning abilities).

Study 2: How teachers intuitively moderate Digalo discussions

Participants

Twenty MA students at the Hebrew university participated. The study was conducted in the framework of a course on the role of the teacher in technological classrooms. The course was delivered at the School of Education. About 90% of the students were in-service teachers.

Procedure

The course consisted of 14 meetings. Although the course describes the various roles of teachers in planning activities (including designing activities with the help of flexible technological tools) and the role of technologies in evaluating learning and teaching processes in general, it focused more on e-discussions and the role of the teacher before, during, and after the discussion. The course included the following themes: (a) the role of the teacher in planning, orchestrating, and evaluating lessons; (b) general overview of possible roles of technologies in supporting such teachers' endeavors; (c) types of classroom dialogues and strategies for sustaining them; (d) familiarization with the Digalo tool for e-discussions; (e) extracting arguments from a text that presents a controversial issue in a Digalo map; (f) discussing the same issue with the Digalo tool in small groups; (g) evaluation of [e-]discussions: ground rules, indicators; (h) scripts for discussions, participation in e-discussions according to agreed ground rules, evaluation of such e-discussions; (i) the role of the teacher in designing [e-] discussion activities; (j) the mediating role of the teacher in [e-]discussions, especially for constructing knowledge; (k) experiencing moderation in Digalo e-discussions and evaluation of the moderation. At the end of the course, the students were randomly assigned into 5 groups (4 students in each group). In each of the groups, one of the students was randomly assigned the moderator's role. The only explanation these moderators received was that they should moderate (run/manage) the discussion according to their own views and/or school experiences. The task the groups discussed revolved around an educational dilemma – whether to give a prize to a student whose achievements are very high, but who shows disdain for his peers and demonstrates anti-social behavior. The participants in each group (excluding the moderators) were asked to choose a role to play: being a school principal, a class teacher, or educational advisor. Each person had to represent the role he/she chose. We should note that although subjects underwent a 28 hours long course, the strategies the students enacted in moderating e-discussions could still be considered intuitive since they only experienced moderation once before.

Results

The discussions yielded 5 Digalo maps that represented the products of the 5 discussion groups. Figure 1 displays two of these maps. Every shape represents a contribution that a participant created throughout the discussion. The links between the shapes shows the rhetoric relationship between the contributions (support, opposition, [neutral] reference). The darkened shapes represent the contributions of the moderator.

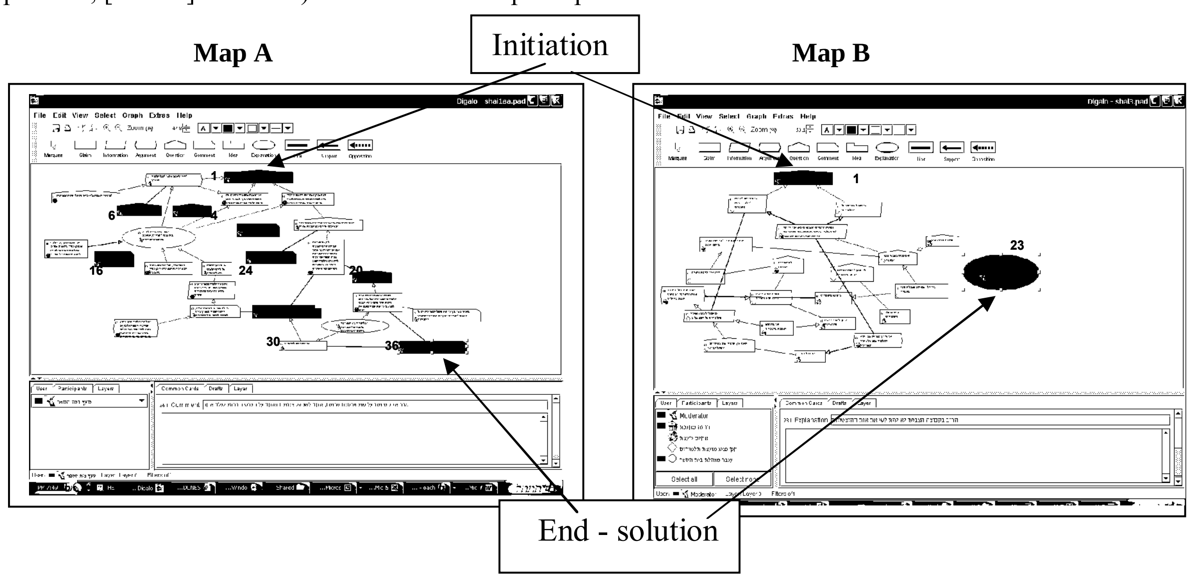

Figure 1: Two Digalo maps built by two different groups

The maps in Figure 1 show two very different types of discussions. In map B, the moderator intervened only at the end of the discussion when the group had to decide on the solution to the problem. In map A the moderator intervened nine times during the discussion. However, although the moderator linked his contribution to the participants, on six occasions no one reacted. So as to identify different moderation practices, we conducted both qualitative and quantitative analyses. In the first stage, we analyzed and characterized the content of the moderator contributions and identified five different moderation styles. We then turned to a quantitative analysis of a number of discussion-map features and examined whether these confirm the different moderation styles identified earlier. We will present the results according to this order:

Content analysis of moderator contributions

Interestingly, the content analysis revealed that each of the five discussion groups was characterized by a distinctively different moderation style:

In group 1 (map A in Figure 1), the moderator encouraged discussants to start the discussion, drew their attention towards the proper choice of ontology, commented on the need to arrange graphical moves on the screen to prevent their overlapping each other, and directed the 'school principal' to a question referring to her. Typical moderator's interventions were *"Girls, what's up. You should express your opinion"* and *"'The principal, a question was asked, please answer it"*. Six out of the nine moderation moves in the first group were identified as aiming to encourage the group members to act. We termed such a moderation move as *organizing moderation*. As it was predominant in group 1, we identified the moderation style as an *organizing style*.

In group 2, six out of the nine mediation moves concerned what we could identify as 'guiding': The moderator presented directive questions and asked for clarifications. For example, the moderator wrote *"I'm sure that your idea is interesting, but can you explain and sharpen your argument more" or "In your opinion, is it enough that Shai excels in learning? What about social value and social relationships?"* We referred to this kind of moderation move *guiding moderation*. As it was predominant in group 2, we identified the moderation style as a *guiding style*.

The moderator in group 3 was not active during the discussion (as shown in map B in Fig. 1). His moderation consisted of presenting the issue to be discussed and the conclusion reached by the group. At the end of the discussion he only summarized the group decision concerning the educational dilemma: *"The group decision is to not allow the award of excellence to Shai*". We refer to this kind of (absence of) moderation an *observing style.*

Six out of the nine moves in group 4 interfered with the flow of collective argumentation. The moderator spelled out his opinion, involved himself as an equal-status participant, to be involved as another discussant. For example he wrote *"It's not true.... Have you forgotten all the problems he caused... or "I am not willing to let him (Shai) stay in school ..."*. We named this moderation move as *involved* and since this move was predominant, we define the style of the moderation as *involved moderation*.

In group 5, all four mediation moves were of an assertive or authoritative type. However, the moderator did not interfere throughout the discussion. He allowed the members to present their views, yet toward the end of the discussion he used his authority in order to 'impose' his solution. He wrote at the end of the discussion *"I think that the teachers should propose a list of recommended children for getting the award , and we will vote for appropriate students from the list"*. We termed this kind of moderation move an *authoritative move*. Since all moderation moves in this map were of this kind, we identified here an *authoritative style of moderation*.

Of course, the five styles we discerned do not represent the full range of moderation styles. One could easily imagine combinations between the styles we identified. Additional studies are needed to identify more moderation styles. However, the information we collected so far not only indicates first directions for research on moderation styles but also on the extent to which such styles are desirable and on how moderators function when adopting them. We analyzed the discussion maps on the following moderation-relevant features: (a) the types of ontology shapes the moderators used; (b) the types of links used; (c) the number of moderator interventions in the Digalo discussion; (d) the distribution of these interventions throughout the discussion; and (e) discussants' responsiveness to moderator interventions. The combined results of these analyses are presented in Table 3, which displays the five aforementioned features of discussion maps for the five discussion groups.

Type of moderator shapes

Table 3 shows a crucial feature of moderation and of the maps in general, namely that the five moderators used different argumentative moves from the argumentative ontology proposed, and this use reflects their moderation style: For group 1, the organizing style of moderation was embodied in 'comment' and 'question' shapes, the style they adopted; in group 2, the guiding style was embodied in 'comment', 'question', and 'argument shapes; for group 3, the observing style was embodied in one 'question' and one 'explanation' shape; in group 4, the predominance of 'argument' and 'claim' shapes reflects well the involved style of moderation; only in group 5, the use of 'idea' and 'question' shapes do not allude directly to an authoritative style of moderation. However, it is clear that the moderator chooses the shapes according to deliberate decisions. This choice expresses that the subjects participated in a course in which they learned to express themselves in e-discussions in terms of a given ontology. *The analyses we conduct concern only students for which the use of the ontology has become fluent to some extent,* since they participated in a preparatory phase in which they learned to use the tool and the ontology in e-discussions.

Table 3. **Features of the discussion maps by moderation style**

	Moderation style				
	Group 1 Organizing	Group 2 Guiding	Group 3 Observing	Group 4 Involved	Group 5 Authoritative
Number of contributions created by moderator	9	9	2	9	4
% of total map contributions created by moderator	33	26	9	30	16
Distribution of moderator interventions (%)					
Beginning	44	33	50	11	25
Middle	44	22	0	67	0
End	12	45	50	22	75
Moderator contributions in terms of shape-ontology (%)					
Claim	0	0	0	23	0
Information	0	8	0	10	0
Argument	0	23	0	43	25
Comment	45	23	0	0	0
Question	45	46	50	13	25
Idea	10	0	0	0	50
Explanation	0	0	50	10	0
% of total map links created by moderator	29	15	24	21	14
Links created by moderator (%)					
Neutral	88	55	50	50	100
Supportive	0	12	0	16	0
Oppositional	12	33	50	34	0
% of moderator contributions discussants responded to	33	44	50	55	100

Types of moderator links

The types of links used by the moderator were not uniform across groups (see Table 3), although most of them were neutral. This finding is not surprising for organizing and guiding styles of moderation. In these cases, the moderator does not express personal beliefs concerning the issue under discussion. For the involved and authoritative styles of moderation, the use of neutral links was more surprising. This seems to suggest that the choice of link type is demanding as it necessitates understanding discussants' contributions in context, and moderators prefer to use a neutral choice.

Relative contribution of the moderator

Another interesting finding in Table 3 concerns the relative contribution of the moderator. Contrarily to classroom discussions held face-to-face, in which teachers are usually very active (Mercer, 1995), it appears that most of the contributions are made by the discussants and not by the moderator/teacher. Here also the frequency in the moderator's contributions reflects the style adopted: For the observing style, it is of course very low, and for the organizing, guiding, and involved style of moderation, it is higher but does not reach more than a third of the overall contributions. This suggests that the students are actively engaged in collective argumentation. For reasons of space limitation, we cannot show here that they are debating ideas and problems amongst each other, challenge or elaborate each other's ideas, and share ‘social’ experiences which are not directly related to the task. The interventions of the moderator are then naturally scarcer.

Distribution of moderator interventions along e-discussions

Table 3 shows another interesting feature of e-moderation: We adopted a timeline approach (de Laat, & Lally, 2003) to observe the distribution of moderation along the e-discussion. Table 3 nicely shows that this distribution is very different for each of the moderation styles: In the middle phase of the discussion, the 'observing' and 'authoritative' did not interact with the participants. On the other hand, the 'organizing' moderator was active in this part of the discussion. The guiding moderator was active as well. For both of them, moderation was an on-going process. Beyond the trivial findings that this perspective opens, it appears that easily computable data such as the distribution of moderation over time can give appropriate information which is compatible with information drawn from direct content analysis of interventions.

Responsiveness of discussants to moderation

The last perspective to which we refer here concerns the responsiveness of discussants to the moderators' interventions. Table 3 shows that for the organizing style of moderation, most of the moderator's contributions remained unanswered. At turn 4, the moderator wrote "*Girls, what is happening…start to sound out your attitudes*". In this move, the moderator encouraged the group toward action, but no place was left for further interaction with the group. At turn 13, the moderator wrote "*Girls, try to make your shapes smaller, so we can read your message easier"*. This kind of moderating action is aimed at drawing the group's attention to handier visual organization of the map. In this case too, no room is left for further interaction between the moderator and the participants. At turn 16, the moderator wrote "*The principal, a question was asked, please answer it*". . . Here the moderator directs the school's principal (a role played by one of the participants) to the question she was asked, asking her to address it. Here as well, there is no place for continued interaction. In this discussion, in one instance only, did the moderator ask for an argument following an argumentation: At turn 3, a student wrote "*In my opinion, Shai does not deserve the title of “Excellent Student*". The moderator asked her subsequently "*Could you give the reason for that*?" After the student gave her explanation, no further interactions developed. In summary, in the case of this e-discussion, the lack of responsiveness of the discussants is natural since the organizing style of moderation is inherently directed at helping without interfering.

In group 2 which was characterized by a style of guiding moderation, nine guidance moves were enacted by the moderator during the discussion, out of which five were not responded to by the participants. In addition, most of the interactions referred to a specific intervention move: at turn 8 the moderator wrote "*Do you think that it is enough that Shai excelled in his studies – what about social values and interpersonal relationship*?” At turn 15 Dina linked her response to turn 8 with a neutral link: "*I am for it (to honor Shai with the award), and what do you think of the idea?*" Although Dina linked her response to the question of the moderator asked her, she did not address it directly. At turn 17, Maria also linked her contribution to the question of the moderator at turn 8 with a link of support: "(*We) come to school not only to study, but also to develop and construct personality. . .*" At turn 19, she reacts again to the same question: "*As a counselor, I think he deserves the prize, not because of the learning issue, but rather due to his influence in the social-personal domain* by using a neutral link. She goes on reacting in turn 24: "*Maybe it is worth noting the social meaning of the prize, and that the person who receives it, gets it not only for what he has done, but also for what he can still do,* again with a neutral link. Finally she reacts also at turn 27: *This prize expresses the school’s ideology as to what constitutes a good student; it does not only mean academic achievement, but also a trustworthy human being*" with a neutral link. It appears that despite the moderator’s mediation to provide further aspects of the issue under discussion, not all the responses are directly connected to the moderated subject itself. In addition, the large number of *one* student's responses to the same mediation is surprising. The small number of references to the moderation makes one wonder: why did this happen? In a post-discussion interview we conducted with the participants, it appeared that the discussants found it hard to distinguish between the contribution of the moderator as a moderator and the roles they had to play. It seems that concurrent flow of information from various speakers caused an overload, hence difficulties to relate to each other. It appears then that the lack of responsiveness of students in this case stems from the difficulty discussants have to take the moderator's guiding intervention into consideration because they are too much engaged in their discussions.

As for the other three groups, responsiveness was high, but this achievement was neither surprising nor interesting. It was not surprising that students responded to the unique question asked by the observing moderator – a question that simply stated the question to be discussed. Also, it was not surprising that in group 4, characterized by involved moderation, the discussants responded to the moderator's interventions, since he acted as a discussant. In group 5, the style of authoritative moderation allowed responsiveness to "orders" at the beginning and the end of the discussion, but, as we already noticed, the moderator did not intervene during (in the middle of) the discussion (see Table 3).

In conclusion, in all discussions except for the 'guided one', the lack of responsiveness did not present a problem in itself since the style of the moderation invited a lack of responsiveness. As for the guided discussion, it was difficult for students to respond. Such a phenomenon is important since guidance is a central kind of moderation with the potential of leading to cognitive gains. It seems in this case that the environment should provide new tools for both the discussants and the moderator to be able to interact.

Discussion

In this study, we identified five styles of intuitive moderation in synchronous discussion: organizing, guiding, observing, involved and authoritative. Cognitive styles derive from abilities, beliefs and constraints of the environments in which persons act. In the case of moderation, the style derives also from practices the moderator/teacher enacts in his/her class. The variety of styles we could identify suggests that antagonist forces influence the behavior of the teachers. On the one hand, teachers in classrooms often see themselves at the center: they make their own decisions, initiate questions, evaluate answers, and reformulate or re-voice them, and generally summarize discussions in classes. They are generally authoritative, and assertive. On the other hand, the Digalo tool encourages autonomy of discussants through interaction with peers. Teachers are certainly sensible to such affordances. This is one of the main findings in Study 1 that showed that teachers believed that good Digalo discussions are different from face-to-face discussions in the classroom. Scrutiny over Table 2 suggests teacher's recognition that good moderation moves are essentially organizational and guiding.

In Study 2, moderators had to act and this was a very different story. In light of the dialogic stance our group adopts in teaching and learning activities (Schwarz & Glassner, 2003), two out of the five teachers showed undesirable moderation styles (authoritative and observing).. The involved style of moderation is not extremely welcomed, either, since the moderator should always be aware of his/her role (however, we think that 'involvement as an equal-status move' – and not a style, may be very good strategy). In Study 2, the subjects attended a course in which we tried to encourage students/teachers to guide and accompany learning processes rather than to use authority for transmitting knowledge. The ground rules we proposed implicitly suggested organizing and guiding styles of moderation. We think that the fact that only two moderators chose these styles may be understood by the difficulty shown by the moderator that adopted the guiding style of moderation in interacting with students. For him, it was difficult to interact and discussants often claimed that they did not notice his contributions throughout the discussion. It appears that the Digalo map created simultaneously by several participants presented an overload both for the students and the moderator. Such a situation requires high concentration from the participants in order to follow the flow of written contributions. It discourages some moderators from guiding and accompanying discussions.

The number of participants in these studies is of course extremely limited. However, in-service teachers programs we currently animate on the use of Digalo in classrooms seem to confirm what Study 2 suggests, the fact that teachers are intrigued by a tool that shows potentialities for learning, but experience difficulties to use effectively. One first step for promoting better Digalo discussions is to provide specific scripts to teachers beforehand in order to help them in facilitating collaboration in synchronous Digalo discussions. The EC-funded ARGUNAUT project (IST-2005027728) is aimed at providing teachers with awareness tools (graphs summarizing participation or links between discussants, pop-ups, messages, etc.) that help them and students in viewing characteristics of the discussion without disrupting the flow of the on-going collective argumentation.

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Using Online Social Networks to Support Underrepresented Students' Engagement in Postsecondary Education

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Abstract: Participation in elective online social networks that enhance learners' connections to their local community and to distant others they perceive as similar may be especially important to the educational attainment and engagement of low-income students traditionally underrepresented in higher education compared to their upper-to-middle income peers. This poster presents the conceptual framework for the design and implementation of an online social network aimed at increasing the educational attainment, leadership and social engagement of such students.

Needs Assessment

Today there is widespread concern about providing equitable access to higher education and equitable learning opportunities for today's youth. Changing demographics in the U.S. over the next two decades, with a disproportionate increase in low-income and minority youth, are projected to lead to a decline in the educational level and per capita income of the U.S. workforce. Research has shown that students from low-income backgrounds do not currently earn admission to college or graduate at the same rates as middle-and upper-income students (NCES, 2001; St. John, 2000). Often these students are also first-generation college students who need more academic, social and other types of supports to stay in college and obtain their degrees than do their more affluent peers (NCES, 2001; Tinto,1998). Initiatives that enhance students' engagement and connections to their local community and with others they perceive as like them, can positively influence students' academic learning, persistence and retention in college (Zhao & Kuh, 2004; Bransford, Brown, & Cocking, 2000; Tinto, 1998).

Moreover, schools and colleges are increasingly concerned with developing technological fluency and 21st century skills among all students (e.g., capacity for creativity, collaborative problem-solving, research, digital literacy, and citizenship) as innovation and "knowledge creation are fast becoming the most important sources of new material and intellectual wealth" (Hakkarainen & Muukkonen, 2006; NRC, 1999; Barron & Kafai, 2006). Online social networking and Web 2.0 technologies offer under-explored solutions to supporting students' social engagement and collaborative knowledge creation in ways we have yet to comprehend (Stahl, Koschmann, & Suthers, 2006; Paavola, Lipponen, & Hakkarainen, 2004). They represent potential changes in the former "read-only" Internet, transforming it into a "read and write" Internet: a simple definition of Web 2.0, in which Internet users have much more control over their "data" in releasing it to certain groups and not others, allowing select groups or individuals to edit or transform a user's original data. While there have been a wealth of editorials of how Web 2.0 social networking tools such as *MySpace* are advancing young people's social lives, there is, to date, a lack of theory-based models and empirical evidence that suggests the educational implications of these networks.

This poster presents the preliminary phase of a design-based research project (Barab & Squire, 2004) involving low-income high school and college students across 14 institutions in an informal online social networking environment. Our goal is to examine whether and how participating in such a network impacts students' educational attainment, leadership and social engagement. Below we introduce our emerging theoretical framework and design implications.

Theoretical Framework

In our increasingly Internet-dependent society, there has been some move away from traditional classroom-based, location-specific instruction to virtual-learning environments. At the same time, the social context within which schools and colleges operate has in some ways moved away from hierarchically arranged, densely knit location-bound groups to social networks where boundaries are more permeable and hierarchies are flatter and more recursive (Wellman, Koku, and Hunsinger, 2006). Although substantial research has been conducted to examine formal online learning communities, fewer studies have tried to illuminate the types of interpersonal interactions, exchanges of support, trust, sense of belonging, and social identity that characterize loosely bound, online social networks of interpersonal ties (not tied to a particular educational program) and how students utilize these ties to advance their education (Wellman, 2001a; Wellman & Gulia, 1999; Granovetter, 1973; Haythornthwaite, 2002).

Penuel & Riel (2007) define a social network as a set of people and the relationships among them. These relationships can be concentrated in small subgroups, and the larger network can be defined in terms of the connections between subgroups. Conducting analysis social networks helps us understand how advice, information, and resources transfer from person to person and from subgroup to subgroup in the social structure. Recently, researchers have begun to use social network analysis to examine educational practices, such as sharing of expertise in online university research networks (Koku & Wellman, 2004) and in teacher networks (Penuel, Frank, & Krause, 2006). The social network approach can further illuminate computer-supported informal learning environments: how such environments affect the structure and functioning of social systems (e.g., within educational institutions) and how social structures affect the way computer-mediated communication unfolds (Garton et al., 1997).

Our emerging theoretical foundations for an online social network architecture aimed at K-12 and college students draws on: studies of *network ties* in the social network literature (offline and online); concepts of *social engagement* and its relation to school engagement; and recent applications of *social capital* in the educational literature. First, the social, informational, or material resources a pair exchanges characterizes their *tie* (Granovetter, 1973). Haythornwaite (2002) argued that as relational ties strength increases from weak to strong, so does the motivation to communicate, the amount of support communicated, and the amount and types of information/resources exchanged. However, strong ties (as occur in families) can require much time and attention to maintain. Donath and Boyd (2004) in studying online social networking sites claim that although *online ties* have been found to be weaker than ties established in real-world settings, such weak ties can prove extremely valuable in the midst of a life change or situation where one's local network is limited. Reviewing the social network literature, Mergel and Langenberg (2006) propose four characteristics that help to predict whether ties are sustainable or abandoned over time: individual, dyadic/group, structural, and content related characteristics. For example, younger, more extraverted actors going through a transition (i.e., college entry) who share preexisting friendship ties, values, or common membership in a group are likely to sustain online ties. Structural characteristics (e.g., whether or not a person is at the core of the network and the presence of "bridge-spanners") and content characteristics (e.g., whether ties are more emotion-loaded) also relate to tie sustainability, with the core network actors and experienced bridge-spanners and emotion-loaded ties as more sustainable.

Second, concepts of *social engagement* have attracted increased attention as a solution to declining academic achievement and retention (Fredericks, Blumenfeld, & Paris, 2004). However, researchers have focused less on the peer group than on teachers as a factor in the socialization of engagement (Ryan, 2000). Students who perceive that race and class constrain their educational opportunities, but who also have social supports that promote the development of agency and strategies for confronting difficulty are more likely to remain engaged in school (Conchas, 2001; Stanton-Salazar, 2001).

Third, a review of the educational literature suggests that social capital, the economic, cultural or symbolic benefits accruing to individuals by virtue of their ties with others, is positively linked to educational attainment and educational development (engagement, motivation, identity-formation). For example, peer group academic values and expectations, number of close friends attending the same school, seeing close friends weekly, discussion about jobs and education with adults were just some indicators of social capital that could positively influence educational attainment and development (Dika & Singh, 2002).

Design Implications

From this initial (condensed) review of the literature we offer the following design suggestions: 1) Ensure that network values (e.g., to graduate from college, become a leader, and support low-income K-12 peers) are transparent and embodied in the design; 2) Organize network activities around collaborative creation of meaningful knowledge artifacts; 3) Trust is a core resource. Create a structure where members can learn quickly about and from one another; 4) Create core connectors by pairing a few team members who already know each other; 5) Ensure that bridge spanners comprise 15% of the network; 6) Ensure that the site offers easy-to-use tools for collaboration, idea-exchange, publishing success stories, and access to outside expertise.

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A complete list of references is provided at http://christinegreenhow.net/research/cscl07paper

Evaluating the Effect of Feedback from a CSCL Problem Solving Environment on Learning, Interaction, and Perceived Interdependence

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Abstract: In this paper, we explore the effect of the form of feedback offered by a computer supported collaborative learning (CSCL) environment on the roles that students see themselves as taking and that their behavior reflects. We do this by experimentally contrasting collaboration in two feedback configurations, one which is identical to the state-of-the-art in intelligent tutoring technology (Immediate Feedback), and one which is based on a long line of investigation of the use of worked out examples for instruction (Delayed Feedback). While our conclusions remain tentative due to the small sample size, the data reveal a consistent gender by condition interaction pattern across questionnaire, test, and discourse data in which male students prefer and benefit more from collaboration in the Immediate Feedback condition where they are more likely to take on the role of a help provider rather than a help receiver while the patterns is the opposite for females.

Introduction

In this paper we present an empirical investigation of issues related to the design of a collaborative problem solving environment that builds on prior work related to the development of intelligent tutoring technology for individual learning. We argue that the state-of-the-art in intelligent tutoring technology has been optimized for success in an individual learning scenario, and that many interaction design issues may need to be revisited in order to achieve success in a collaborative learning setting. In this paper we specifically investigate issues related to the timing of feedback from the intelligent tutoring environment. Immediate feedback involving indications of correct versus incorrect problem solving actions and hints on demand or unsolicited hints during problem solving are the hallmark of state-of-the-art intelligent tutoring technology. However, it is not clear whether such feedback from the intelligent tutoring environment will be helpful or harmful in a collaborative learning setting. This paper investigates the hypothesis that the typical state-of-the-art form of intelligent tutoring feedback interferes with collaborative learning because it can be treated as a replacement for the interaction between students that collaborative learning is meant to encourage. Because math has been a very popular domain for exploration in the intelligent tutoring community, we conducted our explorations in that domain. In particular, we selected fraction arithmetic as a unit of material because of its importance and difficulty for middle school students, which is our target student population.

For decades a wide range of social and cognitive benefits have been extensively documented in connection with collaborative learning. Based on Piaget's foundational work (Piaget 1985), one can argue that a major cognitive benefit of collaborative learning is that when students bring differing perspectives to a problem solving situation, the interaction causes the participants to consider questions that might not have occurred to them otherwise. This stimulus could cause them to identify gaps in their understanding, which they would then be in a position to address. This type of cognitive conflict has the potential to lead to productive shifts in student understanding. Related to this notion, other cognitive benefits of collaborative learning focus on the benefits of engaging in teaching behaviors, especially deep explanation (Webb, Nemer, & Zunita 2002). Other work in the computer supported collaborative learning community demonstrates that interventions that enhance argumentative knowledge construction, in which students are encouraged to make their differences in opinion explicit in collaborative discussion, enhances the acquisition of multi-perspective knowledge (Fischer, et. al 2002). Furthermore, based on Vygotsky's seminal work (Vygotsky 1978), we know that when students who have different strengths and weaknesses work together, they can provide support for each other that allows them to solve problems that would be just beyond their reach if they were working alone. This makes it possible for them to participate in a wider range of hands-on learning experiences. It is in connection with this Vygotskian model of collaborative learning that we see a conflict with the design of feedback, sometimes called scaffolding, that is the hallmark of the state-of-the-art in intelligent tutoring technology and is based on the same principles, and thus designed to meet the same needs. Our hypothesis predicts that the presence of typical intelligent tutoring style feedback in a collaborative problem solving environment will reduce the amount of interaction students will engage in. Furthermore, a reduction in collaborative interaction may then lead to a reduction in the exchange of alternative perspectives on problem solving, thus also interfering with the benefits of collaboration from the Piagetian perspective.

While these cognitive benefits of collaborative learning are valuable, they are not the only positive effect of collaborative learning. In fact the social benefits of collaborative learning may be even more valuable for fostering a productive classroom environment. By encouraging a sense of positive interdependence between students, where students see themselves both as offering help and as receiving needed help from others, collaborative learning has been used as a form of social engineering for addressing conflict in multi-ethnic, inner-city classrooms (Sharan 1980). Some examples of documented social benefits of successful collaborative learning interactions include increases in acceptance and liking of others from different backgrounds, identification with and commitment to participation in a learning community, improvements in motivation, and aptitude towards long term learning (Sharan 1980). These social benefits of collaborative learning are closely connected with the Vygotskian foundations of collaborative learning because the positive interdependence that is fostered is related to the exchange of support, or scaffolding, that we hypothesize will be replaced with the scaffolding offered by the environment where typical intelligent tutoring technology is used.

In our experimental approach, we seek to balance concerns related to internal and external validity by running our experiment as a controlled experiment in a realistic setting (i.e., within a pair of real classrooms using material from their actual curriculum). Classroom settings present experimental challenges because there are always more factors beyond our control than in a lab setting. The two classes we worked with were small, having only 30 students in total across the two sets of students. Thus, with small such sample size, we struggle with issues related to statistical power. To increase our certainty in the conclusions we draw from our data, we consider only significant ($p < .05$) and marginally significant ($p < .1$) effects, making a distinction between these two in terms of certainty. Furthermore, we rely on a form of triangulation, to verify that we see a consistent story across multiple channels of data. We investigate the impact of this experimental manipulation on perceptions about the collaboration revealed by a questionnaire, evidence of learning from tests and quizzes, and a qualitative analysis of the collaborative problem solving process from coded chat logs collected during the collaborative problem solving sessions. We measure process oriented outcome measures such as observed help offered and observed help received through analysis of chat behavior. Furthermore, we measure perceived help offered and perceived help received by means of a questionnaire. We also measure cognitive benefits of collaboration, such as learning as measured by pre to post-test gains in domain knowledge. The data do not support the strong form of our initial hypothesis. Rather, we find a consistent gender by condition interaction across all forms of data we collect in which male students prefer and benefit more from the Immediate Feedback condition while female students prefer and benefit more from the Delayed Feedback condition. While the results we present are not conclusive enough to warrant offering concrete design principles yet, they raise important questions to resolve in subsequent work.

Infrastructure for Supporting Collaborative Problem Solving

In this section we discuss the experimental infrastructure used to conduct our investigation, both in terms of the technology we used and in how we set up the lab where the students worked. Because of its tremendous effectiveness for individual learning with technology, we are planning to build our eventual collaborative learning infrastructure on the foundation of Cognitive Tutors (Koedinger, et. al 1997). Other development work related to supporting collaborative learning in connection with Cognitive Tutors is found in (Walker 2005). Our current infrastructure was built with the Cognitive Tutor Authoring Tools, which support quick authoring of Cognitive Tutor style problem solving systems. As mentioned, the purpose of our study is to explore issues relating the design of the problem solving feedback offered by the environment during collaborative problem solving. The infrastructure used in this study is a simple extension of the typical structured problem solving interfaces that are characteristic of Cognitive Tutors and other tutors in the model tracing tutor tradition. This infrastructure is designed to support experimentation with alternative feedback designs keeping all other aspects of the student's experience constant across conditions.

In our study we are contrasting two designs for feedback from the environment, which we refer to as Immediate feedback and Delayed feedback. These alternative feedback paradigms have been experimentally contrasted in individual learning settings in the past (e.g., Bjork 1994, Nathan 1998). Typically, immediate feedback consists of what is called flag feedback, which signals to students after each problem solving action whether it was correct or not, and hints on demand, which are typically arranged in hint sequences, beginning with less directive hints and ending with more directive hints. In a delayed feedback setting, flag feedback is typically withheld so that students must use their own self-monitoring skills to detect their errors. Furthermore, hints may be withheld altogether or changed in nature so as not to be as focused narrowly on the correct solution path so that students have a greater responsibility for keeping themselves on track. In our study, both flag feedback and hints were withheld from students in the Delayed feedback condition. Instead, when students decided that their solution was complete, they submitted the solution and then were presented with a fully worked out version of the problem, with some explanation about how the solution was constructed. In order to control for information access between conditions, the instructional content in the explanation was constructed by concatenating the content encoded in the hints that students had access to in the Immediate feedback condition.

Based on prior work, we know there are trade-offs between immediate and delayed feedback for individual learning, especially regarding efficiency and retention (Bjork 1994, Nathan 1998). Studies have shown that immediate feedback is more efficient because students are never allowed to stray too far from the correct solution path. Therefore, a shorter amount of time is required to solve each problem, and in practice, students solve more problems (Corbett & Anderson 2002). Yet, other studies show that students get a deeper understanding of material in a delayed feedback setting since they have time to reflect on their errors and also that they have the opportunity to develop self-monitoring skills. This was shown in cognitive tasks such as learning genetics (Lee 1992) as well as in motor tasks such as learning arm movement motions (Schmidt & Bjork 1992). Most state of the art intelligent tutoring systems such as Cognitive Tutors have adopted an immediate feedback approach because in practice, the greater efficiency leads to higher learning gains in an individual learning scenario because of the relatively large numbers of problems students are able to work through. However, we conjecture that the optimal problem solving feedback design in a collaborative learning setting may be different.

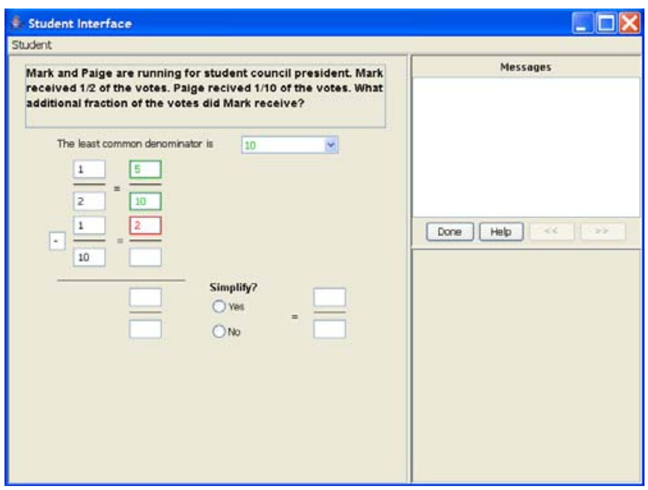

Figure 1. Problem solving interface for Immediate Condition.

As the students worked in the lab session, their computer's display was composed of two panels that were next to one another. In the panel on the left hand side of the screen, displayed in Figure 1, was the problem solving interface. Using RealVNC's Virtual Network Computing (http://www.realvnc.com/), this panel was shared between the screens of the respective computers of a collaborating pair so that they were both free to contribute to the evolving joint solution. In the panel on the right hand side of the screen was an MSN messenger window in which students could chat about their joint problem solving. The arrangement of the lab in which our study was conducted was such that each student was sitting at his own computer in such a way that collaborating pairs could not easily talk face-to-face since in all cases there was a row of desks with computers in between that student's row and the row where the partner student was sitting. The students did not know who their partner was or where they were seated. The purpose of this arrangement was to encourage communication through the chat interface so that it could easily be recorded and eventually processed on line during collaboration.

Method

Experimental Design and Procedure

We designed an experiment to test the hypothesis that if students are working together in an environment in which they can obtain immediate feedback and help from the environment that is always correct, they would be less likely to turn to each other for help and feedback. This hypothesis predicts that in an environment with this form of feedback students would give and receive less help, would perceive less help given and received, and would benefit less from the collaboration. In the control condition, students get immediate feedback from the cognitive tutor (Immediate Feedback condition), whereas the experimental condition students get delayed feedback (Delayed Feedback condition). Both of these feedback configurations are described in detail in the previous section.

The experimental procedure extended over 4 school days, with the experimental manipulation taking place during days two (i.e., Lab Day 1) and three (i.e., Lab Day 2), which we refer to as the first and second lab day since the students worked together in pairs in a computer lab at their school. The fourth day of the experiment was separated from the third day of the experiment by a weekend. Because our study is a within subject manipulation, we used two different units of material, each of which was experienced by each pair in only one condition or another so that we could distinguish learning resulting from work in one condition from learning resulting from work in the other condition. The two units were fraction addition and subtraction (AddSub) and fraction multiplication and division (MultDiv). We counter-balanced the order of the units and conditions in order to control for ordering effects as displayed in Table 1.

Table 1. The experimental setup

	Pairs	Lab Day 1	Lab Day 2
Class 1	1~4	AddSub, Imm	MultDiv, Delay
	5~8	MultDiv, Delay	AddSub, Imm
Class 2	9~11	AddSub, Delay	MultDiv, Imm
	12~15	MultDiv, Imm	AddSub, Delay

On the first day of the four day study, students took a pretest, which lasted for about 30 minutes, to assess how much they knew about the subject matter. We also provided a short collaboration training manual, where the teacher gave an example of good collaboration conversation. In addition, pairs of students were teamed by the instructor. Teams remained stable throughout the experiment. The students were instructed that the teams would compete for a small prize at the end of the study based on how much they learned and how many problems they were able to solve together correctly. The second and third days were lab days in which the students worked with their partner on one of the units in one of the conditions. On each lab day they worked through a different unit in a different condition from what they were in the previous day. Each lab session lasted for 35 minutes. At the end of each lab period, the students took a short quiz, which lasted about 10 minutes. At the end of the first lab day only, students additionally filled out a short questionnaire to assess their perceived help received, perceived help offered, and perceived benefit of the collaboration. On the fourth experiment day, which was two days after the last lab day, they took a post test, which was designed to be isomorphic to the pre test and was used for the purpose of assessing retention of the material.

Subjects and Materials

Thirty sixth grade students from a suburban elementary school participated in the study. The students were from 2 different classes taught by the same teacher, with 16 students in the first class and 14 students in the second class. Students were arranged into arbitrary pairs by their instructor. Students were not told who their partner was. We had a mixture of mixed-ability and homogenous ability pairs. Furthermore, out of 15 pairs who participated in the study, 12 of them were mixed gender pairs, 2 of them were all female pairs, and one of them was an all male pair. Because only a small number of pairs were homogeneous gender pairs, we cannot draw any conclusions from this data about the relative merits of mixed gender versus homogeneous gender pairs. Furthermore, we cannot distinguish between gender effects that are specific to mixed gender pairs, versus gender effects that are independent of group composition.

The materials for the experiment consisted of the following:

- A mathematics tutoring program. The two mathematics chapters were fraction addition & subtraction and fraction division & multiplication.
- 2 extensive isomorphic tests (Test A and Test B) were designed for use as the pre-test and the post-test. These tests each consisted of 16 near transfer and 8 far transfer problems, balanced between the two units of material. Likewise, we had Quiz A and Quiz B, which were designed to be isomorphic to a subset of the pre/post tests. Thus, quizzes are shorter versions of the tests, administered after each lab day. Thus, we were able to use pre to post test gains as a measure of retention (since there was a two day lag between the last lab day and the post-test day).
- Questionnaire. As a subjective assessment of socially oriented variables, we used a questionnaire with 8 questions related to perceived problem solving competence of self and partner, perceived benefit, perceived help received, and perceived help provided. Each question consisted of a statement such as "The other student depended on me for information or help to solve problems." and an 11 point scale ranging from -5, labeled "strongly disagree", to +5, labeled "strongly agree".

Results

Questionnaire

We began our analysis by investigating the socially oriented variables measured by means of the questionnaire, specifically perceived problem solving competence of self and partner, perceived benefit, perceived help received, and perceived help provided. Neither of our experimental conditions maximized all of these outcome variables for both genders. Instead we see a consistent gender by condition interaction across perceived benefit, perceived help received, and perceived help offered, although it is only significant in some cases and marginal in others. Specifically, in the Delay condition boys rated themselves as offering more help and receiving less as well as benefiting less, whereas the pattern was the opposite for girls, although the effect was not as strong.

Consistent with prior work investigating the well known gender gap in math achievement for middle school children, we found a main effect of gender whereby boys rated themselves on the questionnaire as being more competent problem solvers $F(1,29) = 5.01$, $p < .05$, effect size .7 s.d., although there was no significant difference in grade so far in the class reported by their teacher $F(1,29) = 0.46$, p = n.s. There was, however, a significant difference in pretest score whereby boys scored higher than girls $F(1, 29) = 6.13$, $p < .05$, effect size 1.2 s.d., thus demonstrating that they came into the experiment with more prior knowledge about the specific material covered. In terms of perceived benefit from the collaboration, boys rated themselves as benefiting significantly less than girls did $F(1,29) = 2.15$, $p < .05$. As mentioned, there was a significant interaction with condition such that the difference is only significant in the Delay condition $F(1,29) = 4.63$, $p < .05$, effect size 2.5 s.d. This effect did not seem to be related to the relatively higher pretest scores of boys since there was no significant correlation between perceived benefit and either the pretest score of the student or that of their partner. Related to perceived help provided we also found a significant gender by condition interaction $F(1,29) = 4.84$, $p < .05$. Specifically, girls' ratings of the extent to which they offered help was significantly lower than that of boys, but only in the Delay condition. There was a corresponding marginal gender by condition interaction $F(1,29) = 2.62$, $p = .1$ whereby girls' ratings of the extent to which they received help were higher in the Delay condition, whereas the opposite was the case for boys.

Learning Gains

The learning gains analysis is consistent with the interaction between gender and condition observed on the questionnaire and offers some weak evidence in favor of the Delay condition on learning overall. There was no measurable gain on far transfer items either within conditions or over the whole population, thus we suspect that the far transfer items may have been too difficult for these students, and we consider only learning on near transfer items for the remainder of our analyses to distinguish between conditions. We focus first on immediate learning. For our measure of immediate learning, we measured learning gains that occurred locally within each single lab session. Recall that the pre and post test were more extensive than the two quizzes, but contained a section that was isomorphic to the quizzes in order to enable a consistent measure of growth in understanding of the material over the 4 days of the experiment. The post test for each lab session was the quiz administered on the day of the session. For the first lab session, the pretest was the score on the subset of the pretest from day 1 of the study that was isomorphic to the quizzes. The pretest for the second lab day was the quiz score from the first lab day. We only considered data from the 12 out of 15 pairs for which both students were present for the pretest and both lab days.

For this analysis we used an ANCOVA model with post-test score as the dependent variable, condition, pair nested within condition, unit of material, time point, and gender as independent variables, and pre-test score as the covariate. The purpose of this ANCOVA design was to control for all of the factors that may have accounted for performance differences on the test, such as which units of material the students had been exposed to, when the test was administered, and gender (since we observed gender effects in the data). There was a marginal effect of pair on learning gains $F(11,32) = 1.94$, $p = .07$, but no effect of unit of material (i.e., AddSub versus MultDiv) or time point (i.e., lab session 1 versus lab session 2). We see a marginal crossover interaction between gender and condition on near transfer items such that there was a trend for girls to learn more on average than boys in the Delay condition, and for boys to learn more on average than girls in the Immediate condition $F(1,32) = 3.43$, $p = .07$. While it was true that boys came in to the experiment with higher pretest scores, we do not find a significant or even marginal aptitude-treatment interaction that might provide an alternative explanation for the gender by condition interaction on learning.

Because the strongest evidence presented thus far is for the Delay condition to be bad for boys, and only marginally significant evidence in favor of the benefit of the Delay condition for girls, one might argue that the data suggest that the most reasonable implication of these results would be to choose the Immediate feedback condition for all students. However, on the retention test, there was only a significant pre to post test gain in the Delay condition. For this analysis, because each student learned each unit of material in a different condition, in order to measure learning per condition, it is necessary to separate the test questions into subsets related to each unit. If a student learned the AddSub unit in the Delayed Feedback condition, then that student's pre and post test score for the Delayed Feedback condition would be the score on the part of the pre and post tests that were related to AddSub, and the corresponding portions of the tests related to MultDiv would be that student's pre and post test scores for the Immediate Feedback condition. We dropped from the analysis data from segments of material that students were absent for. One student did not take the post test, and 3 students were absent on the second lab day, one in the Immediate Feedback condition and 2 in the Delayed Feedback condition. Thus we have 56 pairs of scores, 29 for the Immediate condition and 27 for the Delay condition.

We computed the significance of the pre to post test difference using 2-tailed paired t-tests. Note that this analysis controls for pair effects and gender effects since all comparisons are for scores pertaining to an individual student. As mentioned, the difference was significant in the case of the Delay condition $t(26) = 1.58$, $p < .05$, but not in the case of the Immediate condition $t(28) = 2.27$, $p = .12$. This is consistent with the findings from other studies in that delayed feedback fosters deeper understanding of the material and thus would be beneficial for retention of the material.

Process Analysis

The student chat logs contain rich data on how the collaborative problem solving process transpired. We conducted a qualitative analysis of the conversational data recorded from MSN messenger in order to illuminate the findings from the tests and questionnaire data discussed above. Based on the analysis of the questionnaire data, we expected to find that boys offered more help in the Delayed Feedback condition but received more help in the Immediate Feedback condition, and that the opposite would be the case for girls. However, we found on the one hand some surprising relationships between chat behavior and questionnaire data and on the other hand more straightforward relationships between patterns in the chat data and how much students learned. Specifically, we find that the condition where students offer more help is the condition where they perceive more benefit and learn more.

In order to make the sometimes cryptic statements of students clearer during our analysis, and also to provide an objective reference point for segmenting the dialogue into meaningful units, we merged the logfile data recorded by the tutoring software with the chat logs recorded with MSN messenger using time stamps for alignment. We then segmented the data into episodes using the log files from the tutoring software as an objective guide. Each episode was meant to include conversation pertaining to a single problem solving step as reified by the structured problem solving interface. All entries in the log files recorded by the tutoring software refer to the step the action is associated with as well as any hints or other feedback provided by the tutoring software.

We approached the design of our coding scheme with some focal questions in mind. For example, we wanted to investigate how many times each student requested help in each condition. Furthermore, we wondered how their partners responded to their help requests. A preliminary cursory analysis of the MSN messenger logs revealed that frequently students requested help but did not receive any verbal response from their partner. We also observed signs of frustration between students and some cases where students explicitly refused to help one another. Because our focal questions all pertain to issues related to help seeking and help provision, we designed a coarse grained coding scheme to identify the regions of the integrated logfiles where this help seeking and help providing behavior is found. In the future we may code additional types of behaviors or make finer grained distinctions. Our current coding scheme has 5 mutually exclusive categories, namely (R) Requests received, (P) Help Provision, (N) No Response, (C) Can't Help, and (D) Deny Help. Along with the "other" category, which indicates that a contribution does not contain either help seeking or help providing behavior, these codes can be taken to be exhaustive. A sample of coded dialogue is found in Table1 where the second and third columns contain the assigned codes. Each column is associated with a single conversational participant.

The first type of conversational action we coded were Help Requests (R). Help Requests are conversational contributions such as asking for help on problem solving, asking an explicit question about the domain content, and expressing confusion or frustration. Not all questions were coded as Requests. For example, there were frequent episodes where students discussed coordination issues such as whether the other student wanted to go next, or if it was their turn, and these questions were not coded as help requests for the purpose of addressing our research questions. Adjacent to each coded help request, in the column associated with the partner student, we coded four types of responses. Help provisions (P) are actions that attempt to provide support or substantive information related to the other student's request, regardless of the quality of this information. These actions are attempts to move toward resolving the problem. Can't help statements (C) are responses where the other student indicates that he or she cannot provide help because he or she doesn't know what to do either. Deny help (D) statements are where the other student responds in such a way that it is clear that he or she knows the answer but refuses to stop to help the other student. For example, "Ask [the teacher], I understand it" or "Hold on [and the other student proceeds to solve the problem and never comes back to answer the original question]" are type D statements. And finally, no response (N) are statements where the other student ignores help requests completely.

<u>Table 2: Example Coded Conversation. Note that for simplicity, portions of the integrated logfile related to the interaction with the problem solving interface have been removed.</u>

Line	S23	S24	speaker: content
92			s24: ur turn
93			s23: k
94	R	P95	s23: is it 1/20?
95			s24: no it is 4/20
96	R	P97	s23: y?
97			s24: cause to get 5 to 20 you need to multiply it by 4 and what you do to the bottom you must do to the top
98			s23: oooooo
99			s23: IM SO SRY
100			s23: :$
101			s24: thats ok
102	R	P103	s23: i feel like a dope
103			s24: :D
105			s23: your turn
106			s24: k
107	P108	R	s24: you have to subtract right
108			s23: yea
110			s24: k
113	P114	R	s24: do you want to do the simplify it
114			s23: Sure
137	C138	R	s24: whats wrong with it
138			s23: idk [I don't know]

Each log file was coded separately by 2 coders who then met and resolved all conflicts. Using this consensus coding, we then tabulated the number of occurrences of each code in each condition associated with each gender. An example of one such interaction is displayed in Table 2. Here students take turns working out parts of a math problem (line 92, 105, 103). When help is requested, the other student provides an answer with some explanation (line 97). Such successful interactions in which students benefit from help received from their partner and also see themselves as contributing to the success of their partner promote feelings of positive interdependence between students (Sharan 1980). In Table 3 we display the average counts of actions within a single problem solving session. We tabulated the codes from the perspective of each student so that for each student we obtained a count for help requests made during the associated session as well as help requests received. We also noted how many problems were solved by that student working with his or her partner during the associated lab session as well as how many conversational segments there were in the integrated logfile.

Table 3 Average numbers (and standard deviation) of coded categories per session. Note that statistical comparisons in the body of the paper are presented both in terms of raw numbers and proportions.

	Males Immediate (7)	Females Immediate (9)	Males Delay (8)	Females Delay (6)
Problems Solved	10.0 (7.19)	6.0 (5.6)	5.0 (2.4)	4.7 (2.8)
Segments	21.7 (11.6)	17.1 (11.2)	15.1 (4.4)	16.8 (3.6)
(R) Requests Received	5.6 (3.3)	2.4 (1.2)	4.6 (3.5)	6.5 (4.5)
(P) Help Provision	3.3 (1.9)	0.6 (0.7)	2.0 (1.9)	3.3 (3.1)
(N) No Response	1.7 (1.4)	1.3 (1.1)	2.2 (1.6)	2.2 (3.9)
(C) Can't Help	0.3 (0.5)	0.6 (0.7)	0.1 (0.4)	0.7 (0.8)
(D) Deny Help	0.3 (0.8)	0 (0)	0.3 (0.7)	0.3 (0.8)
R Given	2.6 (0.8)	4.8 (3.4)	5.4 (4.4)	5.5 (3.5)
P Received	1.0 (1.0)	2.3 (2.3)	2.5 (3.7)	2.7 (1.8)
N Received	1.1 (.9)	1.8 (1.4)	2.1 (3.4)	2.3 (1.5)
C Received	0.4 (.8)	0.4 (0.5)	0.5 (0.7)	0.2 (0.4)
D Received	0 (0)	0.2 (0.7)	0.25 (0.7)	0.3 (0.8)

As a manipulation check, after we tabulated the number of occurrences of each code in each integrated log file, we first checked to see whether there was a significant effect of condition on patterns of occurrence of the codes. For this analysis, each count pertained to a single lab session, but we used data from both lab sessions. There was a marginal main effect of condition on number of problems solved $F(1,44) = 3.49$, $p = .07$, and a significant main effect of condition on number of segments $F(1, 44) = 9.45$, $p < .005$, with no interaction with gender. The larger average number of problems solved and larger average number of segments was found in the Immediate Feedback condition. This is to be expected based on prior findings that immediate feedback increases problem solving efficiency. While there was a significantly larger number of conversational segments in the integrated logs from the Immediate Feedback condition, the proportion of segments that contained a help request was not stable across conditions. Thus, there was no significant main effect of condition on raw numbers of either help requests received or offered. There was, however, a significant gender by condition interaction on raw number of requests received $F(1,42) = 4.79$, $p < .05$, and a marginal gender by condition interaction on both help requests given and help requests received when the raw counts are normalized by number of segments: $F(1,42) = 3.62$, $p = .06$ and $F(1,42) = 3.10$, $p = .09$ respectively. In all cases there was no significant or marginal gender effect except in the Immediate feedback condition, where males received more requests than females as well as participating in a higher proportion of discourse segments in which they received a request than females did. In contrast, females participated in a higher proportion of segments in which they made requests than males did.

Taking into consideration that the majority of collaborating pairs were mixed gender pairs, this analysis suggests that in the Immediate feedback condition, we find an asymmetric collaboration pattern in which males appear as the help providers and females appear as the help receivers. To further investigate this finding, we compared counts of response types across conditions, normalized by number of requests. Data from transcripts where no requests were received were dropped from this analysis. There was a significant main effect of condition on number of Can't Help responses such that a larger proportion of requests were met with a Can't Help response in the Immediate Feedback condition than in the Delayed Feedback condition, with no interaction with gender $F(1,42) = 4.86$, $p < .05$, effect size 1.5 standard deviations. This suggests that the nature of help requests may have been different in the two conditions. Our coarse grained coding of the collaborative behavior does not allow us to further address the question of what caused this difference at this time.

For the other three response types, we see a significant gender by condition interaction but no main effect of condition: Help Provision $F(1,40) = 4.84$, $p < .05$; Deny Help $F(1,40) = 3.96$, $p < .05$; No Response $F(1,40) = 4.91$, $p < .05$. For girls, the proportion of Help Provision and Deny Help responses is lower in the Immediate Feedback condition than in the Delayed Feedback condition, but higher for No Response responses. The pattern is almost the opposite for boys, where proportion of Deny Help responses remains stable between conditions, but the proportion of No Response responses is lower in the Immediate Feedback condition than the Delayed Feedback condition, and the proportion of Help Provision responses is higher in the Immediate Feedback condition than the Delayed Feedback condition. Thus, the asymmetric collaboration pattern reverses directions between conditions when we examine responses to help requests. Whereas girls offer more help in the Delayed Feedback condition, boys offer more help in the Immediate Feedback condition.

We examined relationships between patterns of occurrence of those codes in the collaborative process and the quantitative social and cognitive outcome measures coming from the questionnaire data and the tests and quizzes. These findings are described in the following two sections. Our purpose has been to inform the design for a collaborative learning environment that will enhance positive interdependence between students as well as facilitating learning. However, based on the questionnaire data, neither of our conditions consistently maximized all three of our socially oriented dependent variables, namely perceived benefit, perceived help received, and perceived help offered. The surprising finding is that it appears that girls perceive themselves as benefiting more and receiving more help in the condition in which they are actually offering more help, and conversely, boys see themselves as receiving more help and benefit in the condition in which they are offering more help. Specifically, what we found was a male preference for the Immediate feedback condition and a female preference for the Delayed feedback condition such that girls perceived themselves as receiving more help and more benefit in the Delayed Feedback condition, whereas the pattern was the opposite for boys. In terms of perceived help offered, there was no difference between how girls and boys rated themselves in the Immediate Feedback condition, but girls rated themselves as offering significantly less help in the Delayed Feedback condition than boys did. As mentioned, what we observed based on our corpus analysis is that girls responded to a higher proportion of help requests with a substantive answer in the Delayed Feedback condition, whereas boys responded to a higher proportion of help requests with a substantive answer in the Immediate Feedback condition.

One possible explanation for perceiving more help where one is in fact offering more help is that the act of offering help is an instructionally beneficial activity, and then when students engage in this activity, they perceive themselves as receiving help and benefit because they are learning. Recall that in the learning gains analysis reported above with the quantitative analysis, we observed that girls learned more in the Delayed Feedback condition where we see them offering more help, whereas boys learned more in the Immediate Feedback condition where we see them offering more help. As further evidence of this connection we see a significant correlation between total number of Help Provision responses and learning when we compute a multiple regression with pretest score and number of Help Provision responses as independent variables and posttest score as the dependent variable ($R2=.84$, $p = .001$, $N=30$) and a significant gender by condition interaction on total number of Help Provision occurrences that mirrors the earlier analysis with respect to proportion of Help Provision responses $F(1,26) = 7.79$, $p=.01$. A Bonferroni posthoc analysis reveals a marginal difference between number of Help provision statements made by girls in the Delayed Feedback condition and that in the Immediate Feedback condition (effect size .89 standard deviations) and a marginal difference between number of Help provision statements made by boys in the Immediate Feedback condition and by girls in the Immediate Feedback condition (effect size .86 s.d.).

Conclusion

We have investigated the hypothesis that the presence of typical intelligent tutoring system style feedback in a collaborative problem solving interface would interfere with collaboration and dampen its positive effects. While our data do not support the strong version of this hypothesis, we are left with the challenge of reconciling the dichotomous needs and preferences of girls and boys. Further experimentation is required to identify a satisfactory solution. One obvious follow-up study that we plan to run is to replicate the design from this study except using only homogeneous gender pairs rather than mixed gender pairs. This would allow us to separate gender preferences that are specific to mixed-gender pairs from those that are more generally gender based. Further analysis of the data from this investigation might yield additional insights that would allow us to identify other possible ways of reconciling the different needs and preferences of girls and boys. For example, while we have evidence that our experimental manipulation lead to increases in productive behavior for learning in one condition for boys and the other for girls, we do not know why they responded more positively to different conditions. There may be deeper differences in the interaction styles characteristic of each feedback condition that are obscured by our coarse grained analysis of the data. We believe a deeper analysis of our conversational data would yield new insights.

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Reality television, fan behavior, and online communities of practice

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Abstract: In this paper, I describe participation in reality television online communities as a case of "cultural convergence" (Ito, in press; Jenkins, 2006) across "old" fan fiction and "new" online community practices. The ways in which reality TV fans engage as media producers parallels the ways in which researchers who study other new media such as video games describe the rich discourse, enduring community, and media mixing required to participate in these settings (Ito, in press; Steinkuehler, 2006). I argue here that the characterization of these worlds as *communities of practice* (Lave & Wenger, 1991), the dominant analytic framework for online communities, does not fully capture the way learning (and therefore becoming) happens in reality TV online communities and suggest ways to reframe this model. Finally, I propose directions for future research focused on understanding reality TV online fan communities as informal learning environments that require participants to engage in rich cognitive and sociocultural media literacy activities.

Reality television, communities of practice, and the new media literacy

In this emerging strand of media literacy research, I bring together three different bodies of work – media studies and the culture of fandom (e.g. Ito, in press; Jenkins 1992, 2002, 2006), communications studies with a focus on reality television (e.g. Nabi et al., 2003; Reiss & Wiltz 2004; Thompson, 2001), and learning sciences research around online learning communities (e.g. Barab, Kling, & Gray, 2004) - to describe how fans of reality television participate in online learning communities. Much research around online learning communities takes Lave and Wenger's (1991; Wenger, 1998) seminal *communities of practice* theory to characterize learning in these environments. Distilled from extended studies of apprenticeship practices such as tailors and butchers, the central metaphor for learning, and therefore becoming, is a developmental progression from legitimate peripheral participation to full participation over time. Barab et al. (2004) define online learning communities as, "persistent, sustained [socio-technical] network[s] of individuals who share and develop an overlapping knowledge base, set of beliefs, values, history, and experiences focused on a common practice and/or mutual enterprise" (p. 23). While this definition captures the features of reality TV online learning communities, the hierarchical view of learning, movement from legitimate peripheral to full participation, does not capture the way reality TV online communities function, nor does it describe the way participants become community members. A primary reason for this disconnect, I believe, comes from the treatment of literacy in traditional communities of practice as the consumption, critique, and (sometimes) production of text. Ito (in press) argues that new media literacies blur the line between production and consumption, disturbing our traditional conception of legitimate peripheral participant as consumer and full participant as producer. Here, I treat the literacy practices embedded in participation in reality TV online communities as a productive technology-based, multi-modal activity that allows participants to master the design grammar by which messages are effectively communicated across these various media, many of which are non-text based (Gee, 2003; Ito, in press).

While "reality television" has been around since *Candid Camera* debuted in 1948, *The Real World* precipitated a wave of new shows (Thompson, 2001) that comprise distinctive television genre, defined by Nabi et al. (2003) as, "programs that film real people as they live out events (contrived or otherwise) in their lives, as these events occur" (p. 304). Early studies of television fandom in online communities (Jenkins 1992, 2002, see also Baym, 1999; Lancaster, 2001) looked at Usenet groups around shows such as *Twin Peaks*, to understand the construction of meaning and the production of cultural artifacts through participation in these communities. These studies, however, could not have possibly predicted the explosion of technological innovation that would result in the creation of online communities as rich and sophisticated as massively multiplayer online games (MMOGs) (Gee, 2003; Steinkuehler, 2006), fantasy sports (e.g. Jenkins, 2002; Smith & Sharma, 2005), and learning communities across the k-16 system (Barab, et al., 2004). While the information sharing, text production, and dialoging that Jenkins, Baym, and Lancaster describe are integral parts of these communities, participation in online communities necessarily means participating in social and material practices beyond the comprehension and composition of text, in both synchronous and asynchronous spaces (Steinkuehler, 2006). Extending the work of Jenkins (2006) on cultural convergence and reality television, I argue that reality television online fandom serves as the prototype for modern cultural fandom and the expression of that fandom through multi-modal online communities of practice.

Participation in reality TV online communities

Along with the recognition that participation in new media television fan communities involves much more than the consumption of a variety of texts comes the need to describe and classify what it means to participate in these communities. Ito (in press) characterizes participation in communities such as these by, "[a shift in] structures of participation in the production/consumption matrix." Learning in online communities such as these cannot be defined by the traditional dichotomy of production and consumption; reality television show fans are more than just television watchers – they are producers of a participatory cultural experience (Jenkins, 2006). Drawing from models for participation outlined by Ito and Jenkins, I propose two primary ways in which the model for learning in reality TV online communities differs from the often-employed communities of practice framework: 1) the trajectory for learning is non-hierarchical linear and, as a corollary; 2) the tools, venues, and products involved in participation (and therefore becoming) are dispersed. I will provide brief examples of each of before turning to a research agenda that can explore this model for learning in new media literacy environments such as these.

Trajectory for learning as non-hierarchical

There are myriad ways of becoming a member of a reality TV online community, all of which require different literacy practices, methods for participation, dedicated amounts of time, and interaction with others. While I have not yet unpacked all of the trajectories for learning involved in participation, some popular forms of participation include: critique; immersion and; "fantasy" play. Critique is likely the most popular form for participation, and is also the most similar to the prototypical structure for participation in online TV fan communities described in earlier studies. Participants engage in critique primarily through a weblog, opportunities for fans to express their opinions and dialogue with one another about the show, the contestants, the judges, and any information relevant to the show. While participating in a weblog is a popular activity for fans across reality TV online communities, it is particularly interesting to look at weblogging across game show-style reality shows with a job search focus, such as the *Apprentice*, *America's Next Top Model*, or *Project Runway*. The focus of these shows is to choose one person to follow through a series of challenges related to core competencies in the given profession, who is anointed by a group of industry professionals as "the next big thing" in their field. Since competitions are centered on identifying "the best" contestant in their field, weblogging serves as an opportunity for fans to try out and demonstrate their knowledge of that field by sharing their opinions on contestants' products as well as judges' choices.

What if, however, as a fan of a reality show, you are more interested in how contestants will fare than in a sophisticated, critical analysis of the show itself? Competitive fandom as a model for participation draws heavily from the world of fantasy sports, where players take on the role of team owner and assemble teams of real-life ball players to accumulate the players' statistics throughout a season. The *New York Times* (May 16, 2006) reported that 15 million people spend 1.5 billion dollars annually on fantasy sports, creating an active, participatory culture around online sports fandom. The metaphor of "owning a fantasy team," has been seamlessly and enthusiastically embraced as another participation structure for reality TV fandom. For example, through fantasysurvivor.net, participants can earn points by choosing who on the show will win challenges, be voted off the game, be immune from voting, and other in-show categories. As of the writing of this paper, there were 646 independent leagues registered on the website, with a variety of different community characteristics including public or private and free or with charge.

Finally, reality TV has begun to capitalize on the popularity of MMOGs, and particularly Second Life, immersive digital worlds where users take on virtual selves. MTV's documentary-style show, Laguna Beach, chronicles the lives of privileged high school students living in a town in Orange County, California. Through MTV's website, Laguna Beach fans have the opportunity to create an avatar within the Laguna Beach world, inhabit places the show's characters inhabit, and participate in virtual Laguna Beach events including throwing parties, attending concerts, and shopping (http://www.vlb.mtv.com). From these brief descriptions, it easy to see how the practices embedded in these forms of participation are vastly different, do not necessarily require mutual participation, and all represent reality TV fandom in different ways.

Tools, venues, and products involved in participation are dispersed

The communities to which these participants belong are not mutually constituted, and not simply because some watch *Survivor* while others are hooked on *The Apprentice*. The three activities described briefly above constitute fundamentally different modes of participation in reality TV fandom. Part of the reason for this is that fans have access to a rich set of media tools, from which they can pick and choose to learn about and from and to use across these different trajectories of community membership. Media tools used for participation include: anytime access to past series episodes, access to "never before seen" footage, opportunities for conversations with show contestants or "characters," through web chats, web casts, or by their reading online journals. These multimedia tools contribute to the constellation of literacy practices in which fans engage, facilitating their capacity as media producers. For example Bravo TV, the network that sponsors *Project Runway*, (a show focused on the profession of fashion design), gives fans the option of creating their own runway shows, using fashions created throughout the life of the show, from both winners and losers. Using a simple drag-and-drop interface, participants can select clips, music, and special effects, share their videos and rate others' videos. In this way, fans have the opportunity to "try on" the role of designer, creating a hybrid construction of work from multiple designers, reframing the original work through a fan's eyes.

Future studies on reality television, participation structures, and online communities

In this paper, I have argued why reality television represents the prototypical domain for a new media literacy version of fandom and the online communities created as a result. Additionally, I proposed that the *communities of practice* framework for understanding how learning looks in these communities is appropriate, but incomplete, considering the myriad participation trajectories available that do not necessarily mirror the hierarchical movement from legitimate peripheral to full participation outlined in Lave and Wenger (1991) and the literature around online communities. I have begun to describe what these participation structures look like, but this is simply the beginning of a line of research aimed at understanding reality TV online fan communities as prototypical examples of cultural convergence. The strand of participation I have termed "competitive fandom," seems a fruitful line of research aimed at characterizing learning as consumption *and* production that disturbs the peripheral to full participation hierarchy.

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Principles and Grand Challenges for the Future: A Prospectus for the Computer-Supported Collaborative Learning (CSCL) Community

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Abstract: Six principles of future learning environments have emerged from the CSCL research community. These include: greater "sightlines" into learner, teacher and peer cognition; an increasingly salient role for modeling; increased connectivity between people, concurrent with a greater sense of individualization or "one-to-oneness"; fluid contextual mobility in learning, such as between virtual and real contexts or interoperability of individual, social and machine knowledge forms; and higher interactional bandwidth, or capacity of the environment to mediate meaningful content. Four grand challenges – large, worthy, and difficult tasks should occupy the attention of the CSCL community. Each is a frontier: a more visible and vibrant role for the tools and metaphors of the CSCL community in a troubled era of globalization; means for extending collaboration beyond cognitive models to a broader range of human experience; vitality in learning and collaboration through the life cycle; and unlocking group "flow" in the science of collaboration.

Introduction

There are two purposes to this paper. The first is to discuss six principles or metaphors for learning environments of the future. The second purpose is to identify four grand challenges for the CSCL research community. The paper thus takes the form of a prospectus for directions that are underway as a result of work by this community and for directions that are possible. A grand challenge can be taken to mean a large task for the community, one that is vital, difficult and noble. It can be simply formulated, as in "put a man on the moon." In this context, though, attainment is evolutionary and not readily documented by a single event but rather by a pattern of events and trends. Grand challenges are worth organizing people and resources. The outcomes of a grand challenge are not certain and the consequences of failure are high. In contrast, the principles of future learning environments are in motion. What is at stake in not whether we realize or attain these principles, because in fact they are being realized. What is not known is how thoroughly the principles are elaborated -- and how well the community exploits them to accomplish the larger grand challenges.

The paper is prepared from a somewhat unusual background as a former division director at NSF involved in funding and in being able to observe many of the most important research projects in this community until 2003. More recently, our research center at the US Air Force Academy (USAFA) has been involved in developing and researching new approaches to future learning environments, with NSF-supported work in networking pedagogical agents over collaborative workspaces using new interfaces (2004) and in advancing work originated by Lesh, Kaput and others on models and modeling as a foundation for future mathematics education (Lesh, Hamilton et al. 2007). Additionally, we have organized various research community development projects under NSF support in the areas of new teaching pedagogies and more recently in distributed learning and collaboration (e.g., Hamilton, Carmona et al. 2006). These three vantages – as a funder, as a researcher developing new learning environment frameworks, and in research community development – contribute to the analysis here of principles for future learning environments and grand challenges for the CSCL community.

The six principles are not meant to be provocative so much as to encode some of the large accomplishments of the field and to suggest some important aspects of them. There is no shortage of candidate principles, or indeed of potential grand challenges for the future for the CSCL community. This paper does not claim to offer ideal formulations. Bell and Sabelli (2006), Koschmann and colleagues (Koschmann, Hall et al. 2002; Bereiter, Koschmann et al. 2004) and others have reflected on CSCL directions and have encouraged dialog about those directions. They have forcefully advocated deepening the integration and strengthening of the multiple theoretical frameworks that guide the community. That integration is an ongoing and daunting task. While this paper cites work from multiple theoretical frameworks, such integration is beyond the paper's contribution. The central goal of the paper instead is to stimulate additional discussion within the CSCL community about the ways we describe future learning environments and the ways we understand the largest, most vital and consequential tasks on our horizon. Do these resonate? Do they clarify where we are going and where we should go? What might be more accurate or insightful ways to describe forward progress, opportunity and responsibility?

- *Increased sightlines in the classroom* – a greater ability for everyone in a classroom, teachers and students alike, to see usable representations of conceptual models used by others in the classroom;
- *Increased emphasis on models and modeling* – a greater stress on systems of ideas and relationships both in how learning "tasks" are structured and in how assessment is carried out;
- *Increased connectedness* – learners more meaningfully connected to each other and those outside of the classroom;
- *Increased "one-to-one-ness"*– greater individualization and customization for the individual learner under the management of a teacher, emulating a one-to-one tutoring experience.
- *More fluid contextual mobility in learning* – transfer to and from virtual systems, greater emphasis on heterogeneous competencies functioning at unison, greater integration of cognitive, social and affective dimensions of learning, more hybridization and interoperability of individual-social-machine knowledge forms.
- *Increased interactional bandwidth* – the capacity of the learning environment to mediate meaningful content and affective representations that are shared by participants in that environment.

Table 1: Six Principles of Future Learning Environments

Two more preliminary notes. For the purposes of space, much of the discussion below, at least on principles of future learning environments, is confined to P16 formal educational settings. Such settings may include physical classrooms or more distributed and/or online settings. Many elements of these principles characterize other types of environments, such as companies or networks as "learning organizations" or broader social structures and communities. These principles, while not comprehensive, are attempts to be both simple in formulation and deep in substance. The discussion of grand challenges is not confined to formal educational settings. Second, the expression "computer-supported collaborative learning" conveniently fixes some baseline assumptions about the CSCL research community. Its principal pursuits are about deep and effective collaboration, about deep and effective learning, and how collaboration and learning can interact and enhance one another. Investigating how information and communication technologies such as computers mediate or help to co-create learning and collaboration as the central work of the community is a given. That is, these themes can rightly be stipulated as both principles of future learning environments and grand challenges. Given that stipulation – that we are all seeking means to advance deep and effective learning and collaboration – this paper seeks to elaborate on some dimensions of our common quest.

Principles for Learning Environments of the Future

In a recent global colloquium on engineering, our research group summarized three important metaphors and principles for future learning environments (Hamilton 2006), to which this discussion adds three others.

Principle 1: Increased "sightlines" in the classroom

The "classroom of today" is a vague but still useful starting point for any discussion about the future because today's classroom structures commonly have so many evident shortcomings. One characterization, though, that is not frequently invoked may be one of the modern classroom's most deleterious shortcomings. Classroom environments are steeped in a culture of *guesswork by teachers* about what students bring to class conceptually, how they are cognitively and affectively engaged while in class, and what they have learned by the time that a class session or grading period has concluded. And classrooms are steeped in a culture of *guesswork by students* about conceptual structure, what they should know, what is salient to the teacher, and what they know relative to their peers. (Although the latter is to be expected, in collaborative environments the ability to assess the knowledge of one's peers is important.) The mass production classroom is a social structure that requires constant sensemaking inference and speculation by teachers (and students also, in a different way) about what the students are experiencing, and what instructional or classroom management decisions are appropriate based on those inferences and speculations. Of course, successful educators hone their intuitions about their students to an impressive level of accuracy. But we have become so inured and adapted to following large hunches and guesses about learner, teacher and peer cognition that we accept it as a fixed limitation. *It no longer needs to be so.*

And guesswork extends to content matter. Textbooks and other pre-digital tools are inherently limited in exposing structural relationships in mathematical, scientific and social phenomena. Search tools and other just-in-time media are becoming more ubiquitous for instant access to declarative knowledge and data. In this light, most or all of the CSCL community would agree that the traditional but superficial information-dispensing role of schools is increasingly subordinate to a more critical role of building competencies in understanding, connecting, making sense of and manipulating dynamic, complex systems and social structures. This requires, perhaps above all else, greater tools for visual representation of the structure of ideas that are shared and co-generated, and for visual representation of student and teacher conceptual structures. Virtual systems, games and simulations, by dint of exposing new structural relationships, certainly fall into this category.

- Teachers will see learner cognition more clearly.
- Students will see structure more clearly
- Students will see each other's cognitive states more clearly.
- Social cognition will be more visible.
- Students will see teacher cognition more clearly.
- Ontologies and visual maps of cognition relative to content more refined

Table 2: Types of New Sightlines

Learning environments of the future will have a greater functionality in multiplying what might be called "sightlines" into learner cognition. New conceptual and electronic tools for teachers and students – both learners – provide ways to see concepts and cognition far more accurately than in the past. Such classrooms will provide richer and more effective ways to allow a teacher to understand the cognitive and motivational state of students. The CSCL research community has played an essential role in multiplying the lines of sight in learning environments. One of the most vivid examples or metaphors in this area, for purposes of illustration, involves participatory simulations (e.g., Colella 2002; Wilensky and Shapiro 2003; Stroup, Carmona et al. 2005), using visualization tools that a) change the types of mathematical thinking students can undertake; b) allow students to see real-time representations of their own mathematical behavior more clearly; c) allow students to see real-time representations of their peers mathematical behavior more clearly, and d) allow teachers to see representations of the thinking of all of the students. This example is vivid but not lonely. Being able to see more – in terms of cognition, conceptual structure, and social networks -- is an implicit (and often explicit) theme of a large slice of CSCL research.

A very rudimentary example of new sightlines involves classroom or audience response systems (Roschelle and Penuel 2003; Banks 2006), that sample student responses periodically during an instructional sequence. More substantive response, feedback and interaction systems such as the Classroom Presenter (Anderson, Anderson et al. 2007), WriteOn (Tront, Eligeti et al. 2006) and GroupScribbles (DiGiano, Tatar et al. 2006) are now coming on line. Each involves tablet computing and the more powerful knowledge modeling that they permit. One potent example involves the blending of fully collaborative workspace networks of tablet devices, allowing the teacher to see thumbnails or full screens of each student engaged in writing activity (such as in mathematics). When the teacher can see more representations of cognition (such as in a workspace), the role that the teacher exerts will fundamentally shift and become more informed. This applies, further, to tools that give *researchers* a greater line of sight into learner activity. Examples include through innovative video observation systems (Pea, Mills et al. 2004), use of model-eliciting activities (below) and the refinement of ontologies that expose cognitive pathways taken by individuals and collaborative teams (Hoppe, Pinkwart et al. 2005). More examples follow in the discussion of the other principles of future learning environments, because increased sightlines plays such an important role in them.

Principles 2: Increased "modeling" in the learning environment

Modeling and its emphasis on formation of connected knowledge forms, the adaptation of large ideas to new contexts, just-in-time learning, and complex reasoning in collaborative arrangements is a healthy departure from the traditional and persistent tendency of schools to function primarily as dispensers of declarative and procedural knowledge. There are many flavors of modeling in education research. Collectively, they form a viable suite of approaches for rethinking and "re-mixing" curriculum in future learning environments. A common theme in modeling research involves variations of emphasis on systems thinking, abstract reasoning and the role of developing mathematical and scientific interpretations from context. This trend has a well-established lineage in the CSCL community (e.g., Hmelo, Holton et al. 2000; Kolodner, Camp et al. 2003). In science education, the *Modeling Across the Curriculum* (MAC) project (Buckley, Gobert et al. 2004) leads and exemplifies this trend with the development of replacement modules across multiple areas of the high school curriculum. In mathematics, Lesh, Yoon et al (2007) turn a phrase associated with teachers who make "mathematics practical", gently suggesting instead the possibility of making "practice mathematical." Work in mathematical modeling in the curriculum has included a strand referred to as *model-eliciting activities* or MEAs (Lesh and Doerr 2003), that is largely the basis of efforts advocating modeling as a foundation for future mathematics curriculum (Lesh, Hamilton and Kaput, 2007).

NSF's Research, Evaluation and Communication Division (now part of the Division of Research and Learning), which plays a prominent role in supporting PIs associated with this community, routinely has relied on metaphors such as modeling and simulation to describe features of its research investments. Many of those investments fall into the different category of modeling in artificial intelligence. Virtual reality environments, including those that transition games to learning, will simply overpower more traditional instructional environments as their features more authentically structure formal educational goals as primary design considerations that are not subordinate to entertainment design. This community is on the vanguard of such developments (Dede 2003; Galas and Ketelhut 2006; Shaffer 2007; Ketelhut, Dede et al. (in press)). One prominent instantiation of modeling in the future will involve variations of intelligent tutoring systems (e.g., Koedinger, Aleven et al. 2003). Similarly, the interaction of artificial pedagogical agents and avatars is promising. Advances in gesturology, affect, and personality engineering in agents enhance their anthropomorphic credibility and usability (Cole, Vuuren et al. 2003; Baylor and Kim 2005; Maldonado, Lee et al. 2005).

Principles 3 and 4: Increased "connectedness" and "one-to-one-ness" in the classroom

Learning environments that furnish greater sightlines into learner cognition and that emphasize, highlight, or rely on modeling lead to greater connectedness in collaboration. In our "Agent and Library Augmented Shared Knowledge Area" (ALASKA) project we look for ways to use collaborative workspaces and pedagogical agents to allow the teacher to see the work of students as they engage in their own work using tablet computers (Hamilton 2004). Such systems also enable *peers* to more effectively see what their classmates are doing when collaboration is allowed. Another example of the change in sightlines is the nascent movement in open-learner-modeling (OLM) (Bull, Abu-Issa et al. 2005). OLM offers promise to a student giving a better sense of how the learning environment is tracking the student's cognitive modeling, by creating what are called "scrutable models" allowing the student to see how the system is representing their cognition against an ontology related to the particular subject matter.

These are among developments afforded by learning technologies and artificial intelligence systems that increase what teachers and students see in the classroom. They address the primitive of the CSCL community – deeper connectedness, the third principle of future learning environments. Such connectedness is a raison d'etre of the CSCL community. Every paper in this conference reflects efforts to exploit communication technologies to create social spaces that foster learning. The examples highlighted here emphasize how connectedness changes when lines of sight change. Sight that allows one to see the structural contribution of collaborators will be fundamentally clearer and less ambiguous in the future than it is now. Representational tools that clarify or highlight conceptual structure manipulated by others makes deep collaboration possible. They allow structure rather than merely constituent elements to be salient and visible.

The example of OLM is important, because it stretches our understanding of the notion of collaboration – collaboration intrinsically refers to working with *others*, at least by the light of traditional interpretation. Yet increasingly learning scientists acknowledge and investigate the meta-roles of *self* in learning, the self *collaborating with self*. Metacognitive and self-regulatory behavior, for example, corresponds to one set of functionalities observing, managing traffic, and directing other functionalities. Learning environments of the future will not only permit deeper collaboration between individuals, but will permit the individual deeper harmony with himself or herself in learning. Individuals *who become more sophisticated about learning become more sophisticated learners*.

A fourth theme of learning environments of the future involves a reference to another seemingly fixed feature of the classrooms of today, that mass education inevitably requires students to conform to the instructional approach of one teacher per class. Whether the students' learning styles align with the teacher's teaching style is a hit-or-miss proposition, a situation that can only be reliably avoided in one-to-one learning settings with a tutor who can adapt to the individual needs of the learner. Ever since Bloom's classic two-sigma claim of the advantage of tutoring over classroom instruction (1984), personalized or "tutored" instruction has been the idealized contrast to traditional or "many-to-one" student to teacher classroom configurations. One-to-one human tutoring is an impossible-to-attain ideal, yet in the future the metaphor may give way to more realistically attainable means to emulate and exceed that ideal. We use the term "one-to-one-ness" as a metaphor for the cognitive and motivational advantages that can follow from a ratio of one tutor to one student. The advantages include dynamic shifting of strategies of teaching to match a student's learning style, more immediate feedback loops, opportunity to probe for clarifications with no wait states or delays, and more interactions and responses that map intuitively and closely to a perceived affective state. Classrooms that have the greater sightlines and connectedness mentioned above will be positioned to emulate and to exceed the vision of customized learning that a one-to-one model represents. In the ALASKA system we are developing, for example, customization through a method that can flexibly invoke short-term, dynamically available and technologically-mediated help from peers; furnish intelligent or affectively astute virtual agents; furnish tailored digital knowledge resources; use open-learner-modeling techniques mentioned above to give the learner more feedback on learning progressions; and free the teacher's cognitive load from routine instruction to devote cognitive resources to more demanding or complex pedagogical tasks such as those that can be undertaken in one-to-one tutoring arrangements. Each of these features amplifies and diversifies individual resources for learning, resources that were not available when Bloom first enunciated the human tutoring double sigma advantage in 1984. Virtually everything in the learning environments of today is colored and constrained by the economic impossibility of attaining a true one-to-one learner to teacher ratio. Yet, appropriately structured, future learning environments may "work around" or even surpass that goal.

Principles Five and Six: Fluid Contextual Mobility and Increased Interactional Bandwidth in Learning

As modes of collaborative learning, interactivity and new technologies abound, one of the most compelling developments in future learning environments will be how they are combined and how learners and educators transition between them and customize them. The flexible or seamless adaptation of learners to rapidly shifting channels in the environment may one of the most interesting developments of future learning environments. And this contextual mobility is not limited to attentional shifts (such as transfer to and from virtual systems) but to shifts and hybrids that might be more sublime, such as participating in while studying the domain space, or moving in and out of a social network space. Several examples appear in Table 4. The construct of contextual mobility has risen to a prominent place in our ALASKA Project. As a multifaceted scaffolding system, ALASKA requires students and teachers to flexibly move in and out of different modes or function in multiple hybrid modes simultaneously. In some cases, collaborative mediators (which might be a teacher or might be an artificial agent) allow students to seek help and to give help, and to do so remotely. Artificial agents that broker connections and collaborative workspaces lower the cost of such help giving and seeking.

Each of the preceding five principles reflects one of numerous possible ways to highlight important trends that may be useful to understand and to leverage for CSCL research. Each has some intersection with the others. For example, customization in classrooms depends increasing the sightlines so the instructor can calibrate activities on a more personalized basis. Increased sightlines create more connections with the teacher, and certainly between students. Developments of this nature enhance what we have referred to as the "interactional bandwidth" of a learning environment, or the capacity of the environment to mediate meaningful content and affective representations shared by participants and to and compress and layer interactions in that environment (Hamilton, DiGiano et al. 2004). *A sixth principle of future learning environments is that they will entail much greater interactional bandwidth.* We are only at the beginning of understanding how much more bandwidth is possible. In a sense, we are at 9600 bps bandwidth environment when 100Mbs is possible. In system networking, bandwidth in measured in speed, with the effects understood in terms of how much richness (e.g., video versus text) is carried over the connections. In learning environments*, the vision is not for frenetic and high-speed activity, but for depth and layering of interaction with others and with content. It is a matter of intensifying human experience, connection and meaning in learning, in ways we could not imagine earlier, and for more of our students.*

• In and out of virtual and real contexts • Blending real and video face-to-face interactions • Participating in and being part of the content space • Greater emphasis on heterogeneous competencies functioning at unison • Adaptation to interoperable scaffolding from peers, digital content, artificial tutors and teachers • Moving in and out of collaboration, individual effort and reflective activity • Transition in and out of fully absorbing flow states • Interoperability of individual, social and machine knowledge forms

Table 3: Types of Contextual Mobility

Four Grand Challenges for the CSCL Community

These six principles are all inherently optimistic about the prospects for building more effective and humane learning environments, and with good reason. They characterize paths that not only are possible but are already being explored or followed. As the CSCL field continues in the development, theoretical integration and empirical studies that will help incrementally advance such compelling possibilities for the future, it may also be useful to situate the research community more largely relative to a global society. In that spirit, the paper offers candidate "grand challenges" that are less intended to encode developments already under way than to provoke discussion on the larger roles that the community might exert in the future.

Grand Challenge 1: Break-out role influencing society with innovative tools and ways of thinking about collaboration

Conferences on learning technologies and educational research routinely invoke the well-being of society, yet these allusions are often illusions, in the sense that there is a poorly articulated connection between research and society. Virtually everyone in this field has likely grappled deeply with the issues of transferring research to practice. It is not so in all sciences or research endeavors, but in ours, where the research traditions are young, the "laboratories" are complex settings, and research funding is driven by the need to demonstrate impact, connecting research to practice looms large. But perhaps not large enough. The tools and ways of thinking that the community is pioneering are desperately needed in a world where polarization along countless dimensions of human experience is exacerbated, ironically, by the miraculous technologies that few of us could imagine in our youth. Our world is in deep trouble. It is survival-threatening trouble. There is no guarantee that we will not see cataclysmic destruction in our lifetimes in one form or another. Averting such disaster will require a lot of the medicine this research community is brewing. It is in our hands to find ways to instantiate new tools of collaboration in areas or ways that are not typical for this community.

People who understand each other and who collaborate are not eager to destroy one another. I am a civilian researcher in a United States military academy, and believe our best hope for building peace is by building bridges of understanding and generosity of spirit. It is not difficult to say to the CSCL choir that collaborative technologies are a great means to that end. This is not idealism, this is reality. While this community is not the arbiter of the sometimes small, sometimes large, sometimes harrowing conflicts that polarize our cities, country, and global society, it can and should elevate its sense of identity, to understand that it can play an absolutely crucial role in forging deeper understanding between people, and in finding ways to express benefits to one another and to convey and to receive generosity. Good will is a limitless human commodity in the right circumstances. The world desperately needs that endless commodity, to create the circumstances for it to be expressed. In my estimation, it is critical to understand the central importance of building understanding between people and cultures as a responsibility of this research community to civilization and prosperity. The CSCL community has in hand the tools and approaches that can play a large role in cross-cultural bridging.

What might this look like? What are specific ways that CSCL researchers can promote bridge-building? The most imaginative and creative approaches will emerge as the community expands its sense of identity and sees that it has a role in promoting connections in a troubled world. We are just beginning some efforts in this direction in our research group. We are in the process, for example, of carrying out research seminars that entail students from the UK (Hamilton, Lesh et al. 2007) and the US, and from the Peoples Republic of China (Hamilton, Tao et al. 2007) and the US and between the Mideast and the US to work together on finding solutions to specific mini-engineering humanitarian problems involving developing countries. This work is co-funded by the US NSF, the British Economic and Social Research Council, and the Chinese Natural Science Foundation. A related project is now starting involving collaborating engineering students in the Mideast and the US. Distributed teamwork is increasingly prevalent in multidisciplinary engineering design, for example, and it is an ideal area for rapid escalation of international computer-supported collaborative learning. The emergence of

- *Break-out role influencing society innovative tools and ways of thinking about collaboration.* The great research frontier: Deploying CSCL in ways that build substantial, authentic bridges of collaboration in place of polarization.
- *Ultra-deep model collaboration: sharing human experience* – CSCL research is at the center of helping individuals assimilate, share and co-create complex knowledge models. The great research frontier: assimilation, sharing and co-creating models that integrate cognition more fully with broader dimensions of human experience such as affect, motivation, intuition and identity.
- *Agility in learning through the life cycle* – The life cycle is lengthening and changing; work, play and society demand continual expansion of individual competencies and multiple start-from-scratch novice-to-expert transitions. The great research frontier: Agile learning throughout the life cycle.
- *Unlocking group "flow" in the science of collaboration* – Work over the past thirty years has enabled greater understanding of individualized and phenomenological conditions that produce optimal and immersive performance in challenging settings, often called the zone or flow. The great research frontier: Uncovering conditions that permit zone or flow conditions for collaborative teams.

Table 4: Four Grand Challenges

engineering education programs with a humanitarian and developing nations emphasis is a salutary development in this overall movement (Mulrine 2006). Most such programs involve individual courses or course sequences. The Humanitarian Engineering Minor at the Colorado School of Mines in the US, the first of its kind, will hopefully be emulated elsewhere. These typically, however, are costly to expand or to scale, and do not yet capitalize prominently on collaborative technologies. The projects referenced above, with Chinese, British, Mideast and US students will actually involve no face-to-face contact, but will rely heavily on collaboration tools to simulate such contact. The research questions will focus on the scalability of such interactions and the tradeoffs that they involve in genuine model-solving activities. In another network project, we are attempting to link US high school students with students in African countries through an effort originally started by the Quality Education for Minorities (QEM) organization (McBay 2005) and through an African mathematics and science education network organized by Hiroshima University. The goal is to position students to collaboratively solve problems that can be modeled mathematically and that are authentic to each other's societies. Children in Topeka and the Four Corners and Seattle should be communicating with children in Kampala or Rio or Istanbul, and not at the level of pen pals, but in ways that become routine and substantive and build permanent bridges to the future. The sophistication of the collaborative tools we are using – collaborative spaces, virtual agents, voice and video over IP, dynamic web spaces -- is fairly high yet there is limitless potential to grow. The conceptual tools center on theories of models and modeling. Our vision is to promote a robust system of exchanges between students internationally, creating a way of thinking about cross-cultural communication that is not only available, but actively pursued by educational systems in different countries. The vision for the CSCL community is to play an expansive role in finding ways to sustain robust international collaborative learning, and thereby alter evolving definitions and descriptions of globalization.

Grand Challenge 2: Ultra-deep model collaboration: sharing human experience

Largely through representational and computational tools, CSCL facilitates sharing and cogeneration of cognitive models. What is the next level beyond cognitive models? Will collaboration exchange go further than cogeneration and sharing of the conceptual and extend to deeper and more complex modeling processes that engage broader dimensions of human experience? One way to think of this is through the frames of experiential reference. Understanding and integrating multiple frames of references is a key indicator of the research area of intellectual maturity. William Perry (1980) and then the team of King and Kitchener (1994) have delineated stage models for moving from egocentric and narrowly defined frames of reference to more complex reasoning forms that recognize the legitimacy of multiple ways to approach a problem. Currently, it is difficult to find ways to move individuals along a developmental continuum. It may be that a key to nurturing maturation in the adaptation of multiple frames of reference is by understanding more holistically that frames of reference are embedded in a series of human dimensions that extend beyond cognitive boundaries. Some of the broader dimensions include affect, identity, socialization, motivation, and belief systems. Damasio's *Descartes' Error* (1994) highlights how the *cogito ergo sum* of Descartes' mind-body dualism has systematically relegated non-cognitive elements of learning to secondary status. CSCL has reached a certain sophistication in metaphors and methods for collaboration around conceptual or cognitive systems, but not to collaborations allowing individuals to impart a fuller range of meaning that is not only rich with cognitive structure but also with affective valence, intuition, and personal meaning, and have those models shared and understood by their collaborators. That deeper sharing can occur in collaboration is not a special insight, but neither is it deeply understood nor systematically attainable. We are only at the very beginning of that journey.

Grand Challenge 3: Agility in learning through the life cycle

The life cycle is lengthening and changing. Work, play, and society will demand continual expansion of individual competencies and multiple start-from-scratch novice-to-expert transitions over each of our lifetimes and those of our descendants. The "learn then earn" paradigm of 20th century industrial society is fundamentally inadequate for the future. Stagnation in knowledge is an increasingly untenable life strategy. Issues of cognitive vitality throughout the life cycle are increasingly recognized by the many industrialized counties with declining birth rates. The severe pressures from this demographic phenomena are repeatedly stressed in policy documents of multilateral organizations such as OECD as well as national policy commissions. This is especially true in countries such as Japan and China, where the birth rate has fallen below that needed to sustain population levels. While low birth rates mitigate overpopulation, they produce societies whose median age climbs and who rely increasingly on the competencies of an older workforce. By most lights and conventional wisdom, an aging workforce is not as agile or competent in evolving new ways of thinking and using technological tools as younger counterparts. Yet one of the most important advances emerging from brain science has been research in neural plasticity through the life cycle and documentation that knowledge construction and acquisition potentials are far greater in the aging process than previously thought (della-Chiesa 2003). It is fortuitous that science is undermining the myth that agile and rich learning can only occur primarily in youth. Researchers such as Gerhard Fischer (e.g., Fischer and Konomi 2005) are investigating means by which CSCL tools can nurture creativity and continued dynamism and creativity, and reshape what we understand to be the learning potentials through the life cycle. This era is the first in recorded history in which it can be argued that the younger generation has greater facility with the tools and artifacts of knowledge formation and knowledge sharing than the preceding generation, it is also arguable that in the future, a youth-dominant society is one that has failed to exploit the vibrancy of all ages of society.

Grand Challenge 4: Attaining group "flow" in collaboration

Both education research and learning science research writ large involve the quest to optimize human performance in teaching and learning. In that respect, other human performance research domains should be relevant to education and learning science research. An area of research with such emphases on high performance should be of particular interest to the CSCL community. One example involves studies of human flow – optimum performance and creativity in challenging circumstances, entailing deep absorption in tasks that are at the outer edge of the individual's abilities. There are multiple design and emergent factors associated with flow, and most of them are related to how an individual functions in a(n) (learning) environment. Introduced as a psychological construct by Csikszentmihalyi (1975), it has been widely researched – often in the context of examining intrinsic enjoyment or satisfaction while engaged in work or play, fully concentrated absorption whereby an individual loses a sense of time, or optimal or heroic performance in extreme (highly challenging, enjoyable or desperate) circumstances.

The CSCL community has indirectly but very powerfully addressed a sublime question: Can the experience of flow while *learning* be routinely induced, and how? There is very limited research on flow *induction* compared to descriptive, measurement or correlational studies of flow experience. This paucity is even more severe in research on flow in learning (see Shernoff, Csikszentmihalyi et al. 2003). On the positive side, research on areas such as immersive simulations and virtual environments, digital media, and engagement in electronic games has produced mounting evidence that it is possible to structure favorable conditions for high performance and fully engaged activity at the edge of one's abilities. One large challenge for that portion of the CSCL community devoted to virtual reality research is to find and accelerate means for exploiting immersive and high performance play into a broader swath of learning and modeling activities (Klopfer, Perry et al. 2005; Shaffer 2007). *As daunting as that challenge might be, a larger one strikes at the heart of research on flow, namely the transference of this experience from a highly autotelic, individual and private phenomenon to one that is shared by collaborative teams, especially in learning environments.* Modern classrooms, for example, are not structured to induce flow. The basic necessary conditions – lack of distractions, lack of fear of failure, understanding of what to do next, i.e., deep sense of executing a tacit model -- are alien to current learning environments. What is the analog for collaborative teams? It would go from Michael Jordan's history-making *individual* game to open the Chicago Bulls' 1992 NBA Finals against Portland *("…I didn't know what was happening. I was in a zone. What can I say? I don't know how to explain it. You know it's got to end, it has to, but when? It's like it doesn't matter what they do.")* to the stunning rally and come-from-behind *team* win by the Bulls against Phoenix a year later, when Horace Grant and John Paxson passed up a guaranteed layup to tie at game's end. Without hesitation and knowing exactly where each other was on the court, they skipped the tie and in one fluid motion bet the world championship on a three-point shot. It went in. Grant and Paxson were in a collective flow.

Another example is the performance of an orchestra, whose members keep a perfect sense of timing but collectively lose their sense of time. How can such experiences of sublime and deep immersion be routinely approached in our so-often-pedestrian learning settings, and how can high performance and optimally creative collaboration be induced? Is the non-linear jump of consciousness to the stratosphere of individual or collective performance so emergent that it can only be appreciated but not replicated? Perhaps, or perhaps we don't know enough about it to make that judgment. Why not understand it well enough to find conditions that might be likely to elicit it? Especially in the realm of collective performance, the domain of this research community? We have argued that it is at least a researchable question (Hamilton 2007; Hamilton and Hurford in press) for computer-supported collaboration. Research in group flow is a tremendous frontier whose building blocks involve networks furnishing rapid feedback loops, calibration of participant task abilities in a collaborative environment, progressively deep levels of task immersion, shared models of task, and shared models of social structure within the collaborative space. Our research group is trying to understand conditions, adding to these building blocks the facilitating feature of heterogeneous agent network flow to mediate feedback loops. The sort of phenomena we envision is significantly beyond anything we have been able to effect, but we have been able to elicit more sustained engagement in learning settings (Hamilton and Hurford in press), for example. Producing high performance collaboration conditions, including the representational and feedback tools needed for tasks whose calibrations are at the outer edges of a team's competencies, in circumstances of urgency, vitality, or other significant challenge, is a task worthy of the CSCL community.

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Instructional support for individual and collaborative demands in two net-based communication settings

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Abstract. In this paper, we present a study conducted to evaluate instructional support measures for a net-based collaborative picture-sorting task. A combination of a model collaboration presented as an on-screen video to the collaborators prior to collaboration and a collaboration script was developed to support individual cognitive as well as collaborative demands. In a 2x3 factorial design we varied the amount of support as well as the mode of communication in order to test the impact of the support on the collaboration process and performance in net-based interactive and non-interactive communication settings. The results showed an improved collaboration process in conditions with support but no significant effect on the performance measures. The support measures fostered the collaboration process even in the particularly difficult conditions with non-interactive communication.

Introduction

Two persons jointly solving a task in a net-based setting face various challenges: In addition to the individual cognitive demands inherent to a task, cognitive processes and activities have to take place due to the need to interact. The latter include collaborative task-related activities as well as meta-cognitive processes (Dillenbourg, Baker, Blaye & O'Malley, 1996). An important part of the collaborative meta-cognitive processes is related to communication: The collaborators have to establish common ground in order to achieve mutual understanding (Clark & Brennan, 1991) and solve the task together.

Furthermore, net-based communication poses additional demands on the collaborators because of the mostly restricted possibilities for communication. These additional demands differ, for example, depending on the channels available for communication (auditory, visual, text-based) and on the mode of collaboration (interactive or non-interactive) (see Rummel & Spada, 2005a). For instance, in most net-based settings, communication is impeded because the collaborators do not share the same physical environment. Thus, they cannot use visual information of the work context or non-verbal information provided by their partner's facial expression or gestures (Kraut, Fussell & Siegel, 2003). Moreover, some settings that allow only non-interactive communication impede immediate and spontaneous interactions and make effective grounding impossible.

Extensive research on collaboration has shown that successful collaboration and good results do not arise without adequate support (e.g. Slavin, 1995) and that support is particularly important for net-based collaboration (see Bromme, Hesse & Spada, 2005). The main approaches to fostering net-based collaboration have as a starting point either the 'mice' or the 'minds': The 'mice' approach aims at improving the technical environment for collaboration for example by using shared representational tools (e.g. Suthers & Weiner, 1995) or technology for remote gesturing (Kirk & Fraser, 2005). Approaches that take 'minds' as a starting point either support collaboration as it occurs through structuring interaction with collaboration scripts (O'Donnell & Dansereau, 1992; Baker & Lund, 1997) or use instructional measures to promote the skills needed for collaboration (Rummel & Spada, 2005a, 2005b).

However, in order to develop instructional measures, we need to understand in detail what skills are needed to solve a specific task. Studies of collaboration mostly use quite complex settings. As we aimed to examine the role and functioning of communication, we used a remote collaborative problem-solving task that is more restricted and enables a more detailed analysis. The task is similar to the Referential Communication Task (Krauss & Weinheimer, 1966), which has been used a great deal to study communication. However, our task holds more individual cognitive demands, as visual search processes are required to detect small differences between the pictures. In this paper, we present a study conducted to evaluate instructional support measures based upon a first, prior study that revealed the task demands (Bertholet & Spada, 2005). Further details of this previous study will be reported after the presentation of the task we used. The instructional support measures included two levels of support, one for individual cognitive demands and one for collaborative demands, and were designed to foster collaboration in interactive as well as non-interactive settings.

Research questions

We conducted the study based on the following research questions:

(1) To what extent do the instructional support measures have an impact on the interactive collaboration process and outcome?

(2) Does non-interactive collaboration also benefit from the instructional support measures?

Method

The Task Used

In our study, two persons had to jointly solve a picture-sorting task while located in two different rooms. One of the participants assumed the role of speaker and the other took the role of addressee. The task was presented on two displays, and oral communication between speaker and addressee was possible via an audio link. On the speaker's display, sixteen pictures were presented that differed only in terms of minor details. The speaker had to describe nine of the pictures and their order to the addressee (see Figure 1). The addressee saw the single sixteen pictures in a random order and had to arrange nine of them according to the speaker's description. The addressee was able to rearrange the pictures on the target area by using the mouse (drag and drop). Because the differences between the pictures were very small, the participants had to first detect these differences and then the speaker had to design appropriate utterances that enabled the addressee to choose the correct pictures by considering the relevant features. This component of feature detection constitutes the main difference from the classic Referential Communication Task, in which the task demands consist only in the verbal description of clearly different objects. This individual cognitive demand makes the task more comparable to realistic collaborative tasks in which communication often has to take place in parallel to individual cognitive processes.

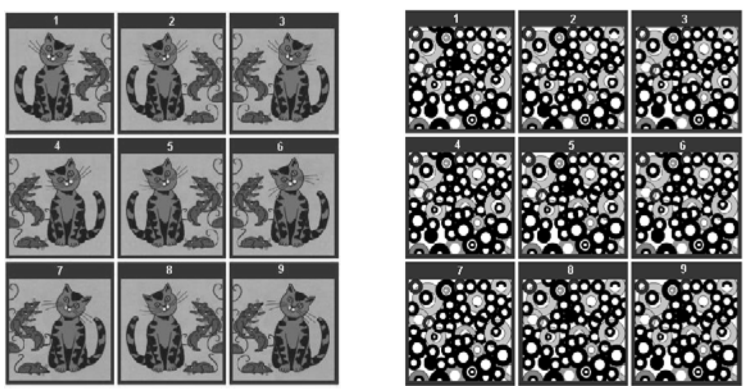

Figure 1. The nine target pictures on the speaker's display for one concrete (left) and one abstract (right) task.

Four different tasks were used, which can be categorized as 'concrete' and 'abstract' sets of pictures (see Figure 1 for examples of both types). Each dyad had to solve all four tasks. The task demands can be grouped into individual cognitive and collaborative demands (due to interaction). The first group of demands includes feature search and identification. The collaborators have to detect the relevant features that differ between the pictures (e.g. the position of the cat, the cat's line of sight, the direction of the cat's whiskers). These demands have to be dealt with individually; they would also exist if the sorting of the pictures had to be carried out by an individual instead of being part of a collaborative task. (The original children's game "Differix" by Ravensburger©, from which we took some of the pictures, consists in arranging nine pictures on a template individually, competing against one to five other players.) The second kind of demands contains the additional challenges of collaboration due to the need to communicate. The speaker has to describe the relevant feature values (e.g. "the cat's whiskers are pointing upwards") of one picture in an appropriate way and the addressee has to understand the speaker's description and to match the description to the features in the picture.

In a previous study (Bertholet & Spada, 2005), it was confirmed that the task does indeed hold individual cognitive and collaborative demands. Furthermore, the results showed different difficulties arising from the two demands for the two sets of pictures: The concrete sets hold more challenges with regard to the individual cognitive demands, and the abstract sets are more difficult in terms of the collaborative demands (due to interaction). As the concrete sets contain familiar objects, the detection of the relevant features is more error-prone because the details can be overlooked quite easily. This result is in line with findings from research on visual processing as the change blindness effect (e.g. Rensink, O'Regan & Clark, 1997). On the other hand, it is more difficult to describe the unfamiliar objects and their features in the abstract tasks because the speaker needs to invent terms and customize them for interaction. Speaker and addressee have to develop a common language in order to establish referential identity (Clark & Brennan, 1991). If they use different frames of reference, this results in specific errors in some concrete tasks. For example, the cat's line of sight can be described from the speaker's or from the cat's perspective. To enable a correct identification of the pictures, speaker and addressee must have a mutual frame of reference.

Interactive and Non-Interactive Communication

Interactive communication is the main setting for language use (Pickering & Garrod, 2004; Clark, 1996). Nevertheless, there are also settings involving non-interactive or less interactive communication such as lectures and speeches or written communication. Non-interactive settings differ from interactive ones in important points, as the speaker does not receive feedback and cannot be certain of having been understood by the addressee: Grounding (e.g. Clark & Brennan, 1991) is not possible. Furthermore, speakers tend to produce longer descriptions if they receive no feedback from their addressees (Krauss & Weinheimer, 1966), they cannot rely on terms used before (lexical alignment; Pickering & Garrod, 2004) and are therefore more careful in designing their utterances (Schober, 1993). When solving a collaborative task together, non-interactive conditions lead to an increased number of errors and it takes more time to complete the task (Clark & Krych, 2004). In spite of this, professional writers such as newspaper reporters still seem to be understood by their audience without receiving feedback, and they must have gained expertise through training and experience in terms of how to write in such a way as to be understood with minimal problems (Traxler & Gernsbacher, 1992).

Taking these results together, it is apparent that non-interactive communication is a very difficult undertaking that needs support. In order to test for possibilities for and effects of support, we included interactive as well as non-interactive conditions in our study and provided both with instructional support measures.

Instructional Support

Fostering 'minds' by using collaboration scripts can improve net-based collaboration. The prominent technique of scripted cooperation (O'Donnell & Dansereau, 1992) aims at optimizing the interaction process by sequencing it into different phases, defining roles, and assigning them to the collaborative learners. As collaboration scripts have shown themselves to be a very effective means for fostering collaboration, they have also been transferred to computer settings (e.g. Baker & Lund, 1997). Typically, they are embedded in computer-based learning environments and guide the collaborators in a step-by-step fashion through different activities. Computer-based collaboration scripts may be used not only to support learners in acquiring knowledge in a specific domain but also to support them in learning how to collaborate (Rummel & Spada, 2005a, 2005b). A second approach provides a *model collaboration* to the participants prior to the collaboration (Rummel & Spada, 2005a, 2005b). While observing such a model of a dyad collaborating, people should reflect upon the solution steps and engage in meta-cognitive activities that promote learning (e.g. Bandura, 1977; VanLehn, 1996). Both approaches have been shown to improve the collaboration, but still entail certain disadvantages: The extensive use of collaboration scripts can disturb natural interaction or cognitive processes and lead to motivational losses (overscripting; see Dillenbourg, 2002). Depending on the amount of information included, the persons watching the model collaboration might have difficulties in extracting and remembering all relevant points.

To combine the advantages of the two approaches, we developed instructional support measures integrating both. Based on the results of a previous study (Bertholet & Spada, 2005) and following the approach of Rummel and Spada (2005b), we developed a model collaboration for the collaborative picture-sorting task. It was presented to the dyads as an on-screen video with audio instructions prior to the collaboration. In addition, a collaboration script reminding the collaborators of what they had just learned before was provided during the collaboration. This combination should promote effective collaboration, as we expect the model collaboration video to have positive effects on the participants' attention and motivation (Bandura, 1977) and the collaboration script to enhance the memory for the relevant information. Both the model instruction and the script contained two levels of support, each corresponding to one of the two demands: level 1 supporting the individual cognitive demands and level 2 supporting the collaborative demands. The instructions mainly concerned the meta-processes to promote effective coping with the two demands. Table 1 shows examples for task-related activities and meta-processes related to the two demands.

Table 1. Task-related activities and meta-processes for individual cognitive and collaborative demands.

	Demands	
	Individual cognitive	*Collaborative (interaction)*
Task-related activities	e.g. Visual search for feature differences	e.g. Description of the pictures
Meta-processes	e.g. Checking whether all necessary features were found	e.g. Establishment of mutual understanding of features' names, frame of reference etc.

Each support level contained hints for dealing with the respective demand (e.g. "In concrete pictures, differences are often overlooked. Please check carefully if you have found all relevant differences.") and, moreover, each level introduced one subtask: Marking the features in an individual picture editor (level 1) and writing the features' names into an individual text editor (level 2). A screenshot of a speaker's on-screen video is presented in Figure 2. It shows the individual picture and text editor on the right.

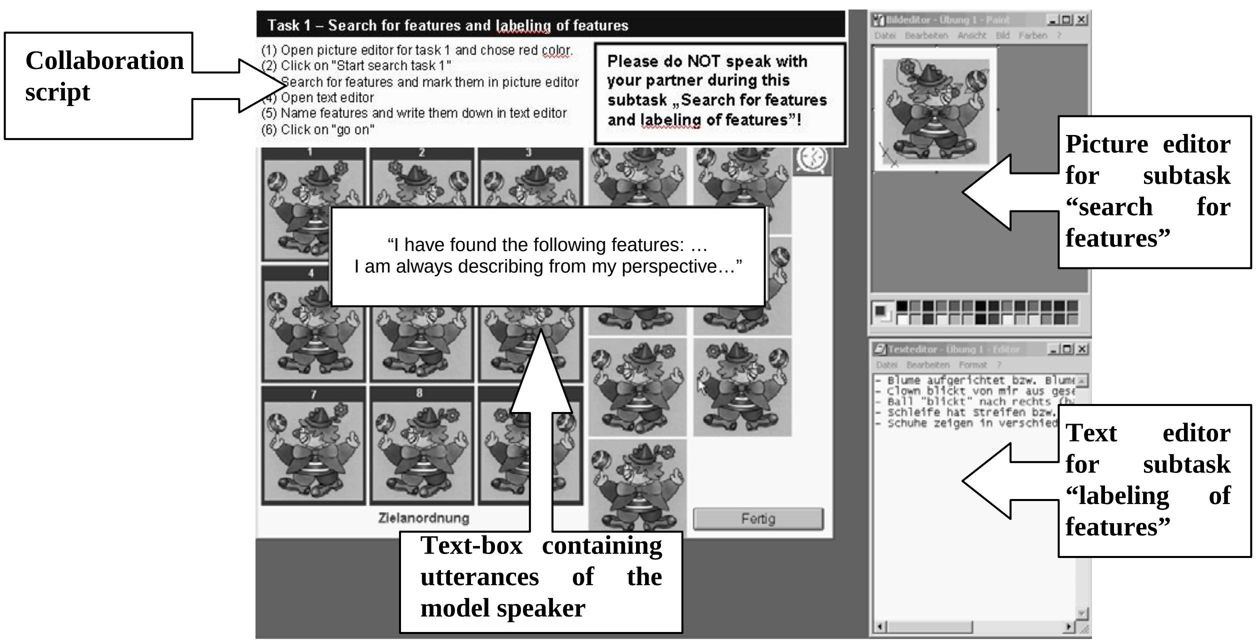

Figure 2. Screenshot of a speaker's on-screen video (condition 'support level 1+2/ interactive mode of communication')

Experiment

Design

A 2x3 factor design was used (see Table 2) with the type of picture (concrete/ abstract) as an additional within-subject factor. Each dyad was required to solve all four tasks but in different sequences: To control for sequence effects, four different task sequences were given. As one between-subject factor, the amount of support was varied (complete support – level 1+2 vs. only support of individual demands – level 1 vs. no support). As a second between-subject factor, the mode of communication was varied, being either interactive or non-interactive. Each participant was assigned randomly to one of the six conditions.

Table 2. Design of the study.

		Mode of communication	
		Interactive	*Non-interactive*
Amount of support	Level 1 + 2 (complete support)	concrete/ abstract	concrete/ abstract
	Level 1 (only indiv. demands)	concrete/ abstract	concrete/ abstract
	No support	concrete/ abstract	concrete/ abstract

Participants

Ninety-six students (48 dyads) from the University of Freiburg, Germany participated in the study. Thirty-six of the participants were male and 60 female. The participants had an average age of 24.15 years (*SD* = 4.4, range = 18 to 48). All participants were German native-speakers. Each participant received 15 Euros for his/ her participation. The participants were randomly grouped into dyads and assigned the role of speaker and addressee. Participants did not know each other prior to the study.

Procedure

Prior collaboration, the participants individually received instructions including technical advices in the form of an on-screen video. Depending on the condition, the video included only technical advices (no support conditions) or further contained the support of the cognitive (level 1 support) or of both demands (level 1 and 2 support). In both support conditions, the participants observed either a model speaker or a model addressee successfully solving a task. Level 1 support contained hints for feature search and introduced the first individual subtask (marking the differences in the individual picture editor). Moreover, level 1 and 2 support included hints for dealing with the collaborative demands and additionally introduced the second individual subtask (writing feature's names in the individual text editor). After watching the on-screen video, the dyads performed a training task (including the description and positioning of three pictures out of sixteen) in order to familiarize themselves with the technical environment and the subtasks. During the experimental phase, each dyad was required to solve four tasks.

In the non-interactive conditions, the speaker and addressee performed the tasks not at the same time, but rather one after another. The speaker had a recording device on the display and could start and stop recording the explanations to the addressee as he/ she desired. A microphone was positioned on the table next to the monitor. The description of each speaker was randomly assigned to one addressee, who later arranged the pictures according to the recorded descriptions. The addressee had an audio-player device on the display and could start, stop and rewind the recording of the speaker's descriptions as often as he/ she desired. However, speakers and addressees in both the non-interactive and interactive conditions were told to proceed as accurately and quickly as possible.

Measures

Two sets of data were collected to examine the collaboration process as well as the outcome: Audio recordings of the communication and performance measures.

The coding scheme for the communication data emphasizes different kinds of problems and errors made during collaboration (Table 3). The categories refer to the two demands on the collaborators: The first two categories to the individual cognitive demands, and categories 3 to 7 to the collaborative demands (due to interaction). The audio recordings of the communication were analyzed using these problem and error categories as well as some additional categories. To check for inter-rater reliability, ten percent of the verbal data was coded by a second rater. The consistency of the coding was medium to high, with $ICC_{just,fixed}$ (intra-class correlation; see Shrout & Fleiss, 1979) between .66 and 1.0, indicating that the coding scheme could easily be used.

Table 3. Coding scheme for the problems and errors occurring during communication.

Individual cognitive demands	
• *Number of not identified features*	How many relevant features were NOT identified?
• *Number of errors 'Feature not mentioned'*	How often did the speaker give descriptions in which relevant features were not mentioned?
Collaborative demands (due to interaction)	
• *Number of features not mentioned before description*	How many relevant features were NOT mentioned by the speaker before starting the description of the first picture?
• *Number of errors 'Name of feature'*	How often did the speaker give descriptions that were ambiguous regarding the feature's name?
• *Number of errors 'Frame of reference'*	How often did the speaker give descriptions that were ambiguous regarding the frame of reference?
• *Number of irrelevant features*	How often did the speaker give descriptions of irrelevant features?
• *Number of complicated descriptions*	How often did the speaker give complicated and pedestrian descriptions of a feature?

The performance measures included: The number of pictures placed in the correct position at the end of one task and the time needed for description and positioning of the pictures.

Results and discussion

We computed a MANOVA with repeated measures (for the factor 'type of pictures') to test the influence of the three factors on process and performance measures. Due to the limited space of this paper, we do not report all of the dependant variables included in the MANOVA, but only the categories described in Table 3. As an ANOVA revealed no effect of the task order, this factor will not be taken into account in the following analyses.

There was an effect of the type of pictures ($F[11, 32] = 16.4$, $p <.01$, $\eta^2 = .85$), an effect of the amount of support ($F[22, 66] = 2.8$, $p <.01$, $\eta^2 = .48$) and an effect of the mode of communication ($F[11, 32] = 9.6$, $p <.01$, $\eta^2 = .77$). Additionally, there was a significant interaction between the type of pictures and the mode of communication ($F[11, 32] = 2.7$, $p >.01$, $\eta^2 = .48$). ANOVAs were calculated for all variables. The results will be reported separately for the process data and the performance measures.

Process Data: Audio Recordings

Table 4 contains means and standard deviations for the process variables included in the MANOVA, with each column corresponding to one factor. Overall, the standard deviations are quite high for most of the variables, showing that there were quite large differences between the dyads. For the type of pictures, there were significant differences in all seven problem and error categories. The results showed that more problems and errors related to the individual cognitive demands occurred in concrete tasks with a higher *number of not identified features* ($F[1, 42] = 49$, $p <.01$, $\eta^2 = .54$) and a higher *number of errors 'feature not mentioned'* ($F[1, 42] = 80.6$, $p <.01$, $\eta^2 = .66$). There was also a higher *number of errors 'frame of reference'* ($F[1, 42] = 14.7$, $p <.01$, $\eta^2 = .26$), because of the need to find a mutual frame of reference in concrete tasks. However, the *number of features not mentioned before description* ($F[1, 42] = 80.5$, $p <.01$, $\eta^2 = .66$), as well as a the *number of irrelevant features* ($F[1, 42] = 28.4$, $p <.05$, $\eta^2 = .40$), both of which are problems related to the collaborative demands, also occurred more often in concrete tasks. This may be due to an illusion of simplicity (Nickerson, 1999) arising for the concrete sets of pictures: When beginning to solve a concrete task, dyads underestimated the difficulties, did not find all relevant features and failed to install a mutual frame of reference. Later on in the collaboration, when the problems became obvious, a high number of irrelevant features were described because the relevant ones had still not been identified. As expected, two problems or errors related to the collaborative demands, t*he number of errors 'name of feature'* ($F[1, 42] = 22.2$, $p <.01$, $\eta^2 = .35$) as well as *the number of complicated descriptions* ($F[1, 42] = 21.8$, $p <.01$, $\eta^2 =$

.34) arose more often in abstract tasks. As can be seen in Table 4, the means of problems and errors during communication differed mostly in the expected way between the conditions with complete support, only support of individual demands and without support: In general, fewer problems and errors occurred in conditions with support. Nevertheless, there were significant differences only in *the number of errors 'feature not mentioned'* (F[2, 42] = 5.2, p <.05, η^2 = .20) and in *the number of features not mentioned before description* (F[2, 42] = 14.1, p <.01, η^2 = .40). As expected, both errors were mostly made by dyads in conditions without support. For the mode of communication, the means of problems and errors during communication also differed mostly in the expected way: Fewer problems and errors occurred in interactive conditions. However, there were only significant differences in *the number of not identified features* (F[1, 42] = 52.1, p <.01, η^2 = .55), in *the number of errors 'feature not mentioned'* (F[1, 42] = 17.9, p <.01, η^2 = .30), and in *the number of features not mentioned before description* (F[1, 42] = 8.4, p <.01, η^2 = .17). As expected, all three errors were made more often in dyads with the non-interactive mode of communication.

Table 4. Means and standard deviations (in parentheses) of the process data.

Dependent variable	***Type of pictures***	***Amount of support***	***Mode of communication***
Number of not identified features	concr.: 2.1 (1.8) abstr.: 0.7 (1.3) **	lev.1+2: 1.4 (1.3) lev.1: 1.2 (1.3) no train.: 1.8 (1.9) *ns*	inter.: 0.5 (0.7) non-inter.: 2.4 (1.5)**
Number of errors 'Feature not mentioned'	concr.: 27.1 (14.3) abstr.: 9.2 (12.6)**	lev.1+2: 14.4 (11.5) lev.1: 15.9 (10.3) no train.: 24.5 (14.6)*	inter.: 12.6 (10.5) non-inter.: 23.7 (13.7)**
Number of features not mentioned before description	concr.: 6.9 (3.2) abstr.: 4.4 (3.7)**	lev.1+2: 3 (2.7) lev.1: 6.2 (1.3) no train.: 7.7 (2.8)**	inter.: 4.6 (3.5) non-inter.: 6.7 (3.1)**
Number of errors 'Name of feature'	concr.: 0 (0) abstr.: 1.2 (1.8)**	lev.1+2: 0.5 (0.8) lev.1: 0.7 (1.2) no train.: 0.7 (0.8) *ns*	inter.: 0.4 (0.7) non-inter.: 0.8 (1.0) *ns*
Number of errors 'Frame of reference'	concr.: 2.7 (4.8) abstr.: 0 (0)**	lev.1+2: 0.5 (0.8) lev.1: 1.4 (3.2) no train.: 2.1 (2.4) *ns*	inter.: 1.4 (2.3) non-inter.: 1.3 (2.2) *ns*
Number of irrelevant features	concr.: 13.7 (13) abstr.: 3.1 (7) **	lev.1+2: 6.9 (9.4) lev.1: 8.3 (9.4) no train.: 9.9 (6.1) *ns*	inter.: 8 (9.9) non-inter.: 8.7 (10.2) *ns*
Number of complicated descriptions	concr.: 0.4 (1.4) abstr.: 2 (3.2) **	lev.1+2: 0.6 (1.3) lev.1: 1.2 (1.6) no train.: 1.8 (2.5) *ns*	inter.: 0.8 (1.8) non-inter.: 1.6 (2.8) *ns*

** p <.01; * p < .05; *ns* no significant effect

There were significant interactions between the type of pictures and the mode of communication for *the number of not identified features* (F[1, 42] = 8.3, p <.01, η^2 = .17), *the number of features not mentioned before description* (F[1, 42] = 8.1, p <.01, η^2 = .16), and *the number of complicated descriptions* (F[1, 42] = 4.5, p <.05, η^2 = .10). In concrete tasks, the number of problems and errors related to the individual demands and in abstract tasks those related to the collaborative demands were higher for non-interactive conditions.

To summarize: The analysis of the audio recordings revealed, as expected, more problems and errors related to the individual cognitive demands as well as more errors 'frame of reference' in concrete sets of pictures. In abstract sets of pictures, there were more problems and errors related to collaborative demands. The developed instructional support measures had a positive effect on the collaboration process, with fewer problems and errors occurring in conditions with support. Indeed, non-interactive communication was more difficult, with more problems and errors occurring in non-interactive conditions.

Performance Measures

Table 5 shows means and standard deviations for the performance measures. The means of correctly placed pictures have to be related to a maximum number of 18 correctly placed pictures. For concrete and abstract types of pictures, the maximum number of correctly placed pictures is 18 respectively (2 tasks x 9 pictures). To keep the mean values comparable, the means of the other two factors were divided by 2. Again, each column corresponds to one factor.

Table 5. Means and standard deviations (in parentheses) of the performance measures.

Dependent variable	*Type of pictures*	*Amount of support*	*Mode of communication*
Number of pictures placed in correct position (max. 18)	concr.: 5.9 (7.5) abstr.: 13 (7.2)**	lev.1+2: 9.3 (7.2) lev.1: 10.3 (6.5) no train.: 8.9 (8.5) *ns*	inter.: 14.4 (3.9) non-inter.: 4.6 (5.2)**
Time needed for description and positioning of the pictures (in sec.)	concr.: 1063.5 (499.4) abstr.: 1057.6 (471.7) *ns*	lev.1+2: 896.2 (371.2) lev.1: 1103.2 (509.2) no train.: 1182.3 (538.4)*	inter.: 1135.5 (483.1) non-inter.: 985.7 (438.4) *ns*

** p <.01; * p < .05; *ns* no significant effect

More abstract pictures were *placed in the correct position* than concrete pictures ($F[1, 42] = 39.1$, $p < .01$, $\eta^2 = .48$). However, there was no significant difference in the *time needed for description and positioning of the pictures*. This also points toward an illusion of simplicity (Nickerson, 1999) occurring for concrete tasks. Dyads without support took more *time for description and positioning of the pictures* than dyads with support of the individual demands as well as dyads with the complete support. Dyads with the complete support were faster than dyads of the other conditions ($F[2, 42] = 2.5$, $p < .05$, $\eta^2 = .11$). There was no significant difference in the *number of correctly placed pictures* between the conditions with different amounts of support. Dyads with the interactive mode of communication placed more *pictures in the correct position* than dyads with the non-interactive mode of communication ($F[1, 42] = 72.6$, $p < .01$, $\eta^2 = .64$). However, there was no significant difference in the *time needed for description and positioning of the pictures* between the interactive and non-interactive conditions. This is due to the significant interaction between the type of pictures and the mode of communication that occurred for the *time needed for description and positioning of the pictures* ($F[1, 42] = 17.4$, $p < .01$, $\eta^2 = .29$). In the interactive conditions, dyads took more time for concrete tasks. If necessary, dyads in the interactive conditions could search for the feature differences together or take additional time for establishing a mutual frame of reference. In the non-interactive conditions, the dyads took more time for abstract tasks; speakers took more time to describe unfamiliar objects if they did not receive any feedback from their addressee.

Discussion and Outlook

The aim of the study was to evaluate instructional support measures designed to support individual cognitive as well as collaborative demands (due to interaction) in a net-based picture-sorting task. The support should foster collaboration in interactive as well as in non-interactive communication settings. The *instructional support measures* included specific help for both kinds of demands realized in two levels. To evaluate the impact of these two levels on the collaboration process and outcome, the amount of support was varied. As it is impossible to give hints for the labeling of the features without emphasizing the need to carefully search for features, the two levels could not be realized independently. To investigate the impact of the two levels, the conditions with level 1 support were only compared with the conditions that received the complete support (level 1 + 2). The analysis of the verbal data indeed showed differences in the problems and errors depending on the amount of support: In line with expectations, the problems and errors related to the individual cognitive demands were higher for the conditions without support and relatively similar in the two support conditions that both received hints for feature search and a subtask with an individual picture editor. The numbers of problems and errors related to the communicative demands were also highest for the conditions without support, but these were relatively close to the numbers of errors in the level 1 support conditions. The differences across the support conditions were significant only for the number of errors 'feature not mentioned' and the number of features not mentioned before description, but for the other problems and errors the means showed the expected tendencies, namely fewer problems and errors in conditions with support. So far, the instructional support measures seem to have improved the collaboration process in the intended way. Unfortunately, the impact of the measures did not reflect on the performance measures unanimously: The complete support conditions did indeed take less time for the description and positioning of the pictures, but there were no significant differences between the numbers of correctly placed pictures for the three support conditions.

A further goal of the study was to illuminate the processes in *non-interactive collaboration* and to test whether the process and performance of non-interactive dyads could also be enhanced by the designed instructional measures. As reported by different authors (e.g. Clark & Krych, 2004), the non-interactive conditions had more difficulties in solving the tasks in an appropriate way. As expected, the numbers of all seven problems and errors were higher in non-interactive conditions (significant differences only for the number of not identified features, the number of errors 'feature not mentioned', and the number of features not mentioned before description). The illusion of simplicity seems to have been higher in non-interactive conditions, since the number of features that the speaker did not identify at all was particularly high for concrete tasks. In non-interactive conditions, the 'need for security' was also higher in abstract tasks, which again gives rise to the supposition of an illusion of simplicity. One main difficulty of abstract tasks is to find appropriate expressions to describe the features. This was especially pronounced in non-interactive conditions, where a high number of complicated descriptions occurred in abstract tasks. The number of pictures not mentioned before starting the description was equally high in both types of tasks, in contrast to interactive conditions, where it was quite low for abstract tasks. The advantage of interactive communication was also evident from the performance measures: The interactive conditions outperformed the non-interactive conditions with a higher number of correctly placed pictures. There was no significant difference in the time needed for description and positioning of the pictures, but as expected, the mean time was slightly longer in interactive conditions. An interesting interaction effect occurred for this second performance measure: Non-interactive dyads took more time to complete abstract tasks, while interactive dyads took more time to complete concrete tasks. This result points in the same direction as the interaction effects for the errors and problems coded from the collaboration process. The illusion of simplicity seems to be more prevalent in non-interactive conditions and at the same time the speaker has more difficulties in finding short and comprehensible expressions for the features in abstract tasks. In line with the assumptions of Clark and colleagues (e.g. Clark, 1996), unidirectional communication or the production and reception of monologues in non-interactive communication is not as efficient as the interactive and bidirectional communication process. The higher amount of time needed for concrete tasks in interactive conditions is presumably due to problems in establishing a mutual frame of reference (Bertholet & Spada, 2005).

To summarize: The dyads without support faced various problems: Speaker and addressee were confused about how to deal with the different demands at the same time, and therefore made many errors. By contrast, the dyads with support seemed to have learned how to collaborate: The collaboration process contained fewer problems or communication errors. For future research, it would be interesting to identify the reason why the improved collaboration process had no impact on the dyads' performance. We took a first step in this direction by relating the number of correctly placed pictures with the time needed for description and positioning of the pictures. We did not include this analysis due to the limited space of this paper. In the support conditions, less time was needed to place a greater number of pictures in a correct position than in conditions without support. It can be assumed that the support might have shown effects on the performance measures in the future; i.e. if more pictures had to be described and positioned. However, further research is needed in order to gain better insights into the possible long-term effects of the instructional support measures. Fostering 'minds' with a combination of an on-screen video containing a model collaboration and a collaboration script to help structure the collaboration process therefore seems, so far, to be a promising approach to fostering collaboration for interactive and also for the particularly difficult non-interactive communication setting. Furthermore, the results suggest the need for both support levels. Particularly for concrete tasks, the support of both demands is crucial and should contain instructions to assure a mutual frame of reference.

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Computational Literacy and Mathematics Learning in a Virtual World: Identity, Embodiment, and Empowered Media Engagement

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Abstract: We are engaged in the on-going development of a computer-supported collaborative learning environment within a virtual world and use it as a setting for studies exploring relationships between student mathematical cognition, computational literacy, and identity. Our design research is informed by the work of Gee (video games), diSessa (computational literacy), Cole (mediated collaboration), Abrahamson (embodied design for mathematics learning), and Lee (cultural modeling). Within the constructed virtual ecology, we are conducting an ethnographic study of a technologically enabled learning environment with real students bearing virtual identities. The participants are physically remote but embody characters with personae of their own making in playful activities that foster intrinsic motivation and bear mathematical and computational integrity that transcends the medium. Collecting both real and virtual data of a group of at-risk urban high-school students working in Teen Second Life, we examine for changes in participants' cognitive–affective dispositions toward mathematical practice and identity.

Our objective is to build an online, computer-supported constructionist learning environment wherein students engage collaboratively in mathematics problem solving activities and develop programming skills. Learning programming skills, a key aspect of developing computational literacy, empowers students to become computational producers and not just consumers (diSessa, 2000; Gee, 2003). This paper reports on our first steps toward creating the online environment: We describe the rationale of our project and its initial implementation. In this study, we focus on the concept of 'recursion' that is key to computer science. Participants ground this concept through computationally constructing the 3D *Fractal Village*, which they inhabit. Fractals are inherently rich visual-spatial representations that, moreover, offer a wide range of cultural entry points (Eglash, 1999). Thus, participants are to appropriate STEM content by constructing immersive aesthetical public-domain artifacts (Papert, 1991).

After researching various possibilities, we chose a digital environment called Teen Second Life, a proprietary virtual 3D world owned by Linden Laboratories (LindenLabs, 2007), as a platform for implementing our project. It is a sister virtual world to the adult world of Second Life. Teen Second Life, a cutting edge multi-user domain (MUD), provides:

(1) a rapidly growing environment with currently millions of unique users (Reuters, accessed 03-19-2007).
(2) a safe environment for minors in a virtual world (adult facilitators must undergo security checks and have no access to the teens' mainland, but only to delimited islands).
(3) infrastructural scripting support that utilizes the Linden Scripting Language. The Linden Scripting Language is designed to be inviting for beginner programmers. For example, many open source library facilities are available, and the virtual-world graphical user interface allows an individual to instantiate objects and directly connect scripts to them.

Theoretical Framework

Socio-cultural accounts of learning (e.g., Cole, 2006; Lave & Wenger, 1991) highlight the roles of artifacts in the mediation of practice-based knowledge. We view the development of fluent, generative participation in mathematics practice as necessitating an agency that goes beyond consuming ready-made tools (Veeragoudar Harrell, 2007). Thus, whereas we intend for users to initially participate peripherally by using ready-made computational objects, as the users gain comfort with the environment they will learn to program custom-made objects.

Intrinsic to the experience of avatar-based participation in virtual environments is the projection of self. Gee (2003) describes this experience as that of coming

> to project one's values and desires onto the virtual character….seeing the virtual character as one's own project in the making, a creature whom I imbue with a certain trajectory through time defined by my aspirations for what I want that character to be and become (Gee, 2003, p. 55).

Thus, relatively unshackled by real-world personal and social constraints, the avatar-based participant can experiment with new practices and dispositions. Specifically, we hope to foster opportunities for participants who harbor negative dispositions toward mathematics in the real world to experiment with an alternative view using constructed identities in a playful, immersive virtual world (see also Powell, 2004).

Design

Visitors to Fractal Village meet a facilitator–avatar who welcomes them with a variety of "fractal seeds" (see Figure 1, below, top-left image)—computational objects for personalizing and nurturing fractals (e.g. trees, art). Completed fractals can be set to change color, size, texture, etc. every time they are touched or at set time intervals. Moreover, a sample object reveals for inspection its underlying implementation (including the recursive procedures).

Figure 1. A facilitator welcomes visitors with fractal seeds (top left). Users customize seed parameters such as size, orientation, texture, color, and movement in space (top right). Fractal seeds are grown into large structures, such as a cylinder tree (bottom left and center). A strong woman avatar flexes her muscles after building her fractal tree (middle right). Having contributed to the flora of the virtual environment, she then turns to improve the aesthetics of the village by building a giant fractal-foot sculpture (bottom right).

When a critical mass of participants is present, activities begin with participants discussing the future of their village and then assigning individual roles and objectives so as to orchestrate prospective construction. During the activities, participants interact, e.g., by sharing code, opining on the aesthetics, and negotiating space. At the end of the process, participants present their constructions and critique their peers' work. Essentially, participants evaluate whether or not the objects created by their peers are in fact fractals. This involves a joint discussion of the components of fractals (recursion and scaling in particular). Thus, with the support of the facilitator, mathematical properties embedded in the fractal objects become articulated through normative vocabulary and constructs.

We foresee a major design challenge is participant heterogeneity in skill, accumulated experience in the village, familiarity with emergent practices, and hours of operation. Moreover, participation should be engaging and rewarding for a visitor who operates in the environment for either 5 minutes or 5 hours. We are hoping to establish international round-the-clock rotating core leadership, such that experienced users are always available to welcome beginners, mentor them, and offer feedback on their initial construction.

Research Question

The Fractal Village project is situated in a larger on-going research program that examines relations between mathematical artifacts and student agency. In a previous study (Veeragoudar Harrell, 2007) we examined cognitive, affective, social, and technological factors contributing to students' mathematical agency. In particular, we suggested that by decoupling mathematical representations from the media in which they are embedded, we can pursue empirically a more nuanced understanding of students' dispositions toward mathematical practice and thus possibly inform the design of computer-based learning environments that support mathematical agency. Findings suggested that students operate differently with representations depending on the media in which they are embedded and that some media are more conducive to mathematical agency. The current study further pushes our line of research by focusing on a more complex medium in which participants' affective as well as cognitive experience may differ radically from traditional school settings. How might students' experiences in a virtual mathematics laboratory affect their dispositions toward mathematical practice? In particular, how might working in Fractal Village impact students' mathematical agency?

Data Collection and Analysis

We have negotiated access to a group of high-school mathematics students and have procured virtual real estate (an "island") where we are creating the technological infrastructure of Fractal Village. We will collect data of student activity, both off- and on-line, including student interviews, video data of real-student participation, streaming screen captures of virtual participation, and classroom-, student-, and teacher interviews. In addition, we will save students' virtual constructions. Data analysis will follow social-science qualitative-analysis methodologies—the project is innovative, and we expect that appropriate analytic approaches will emerge (Glaser & Strauss, 1967) as we conduct the study and begin to understand better how issues of agency play out in virtual collaborative practice.

Demonstration

A demonstration of Fractal Village is planned for CSCL 2007. Attendees will be able to connect as characters within the space, manipulate seed fractals and construct their own recursive artifacts. Also, we will show live activity online and display participant artifacts, sample feedback, and analyses of the learning trajectories.

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Combining Social Network Analysis with Semantic Relations to Support the Evolution of a Scientific Community

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Abstract: This paper presents an analytical approach to support organisational learning in terms of the evolution of a scientific community based on a combination of social network analysis and semantic relations. The primary and direct target of the method is to infer hidden or desirable links between subgroups in a networked community. The data source for these inferences comprises memberships in teams and thematic subgroups. The approach has been applied in a case study to a large scientific network on technology enhanced learning.

Introduction

One perspective of research on technology enhanced learning and scientific knowledge production deals with communities of practice (Wenger, 1999), and especially with the role of information and communication technologies in defining, maintaining and evolving these communities. In this view, networking infrastructures and communication mechanisms are enabling factors for community development. In a more recent article, Wenger, McDermott and Snyder (2002) make a transition from observing and analysing communities of practice towards "cultivating" such communities. The first of seven principles for cultivating communities of practice is the "design for evolution" (as a postulate). In the sequel, we will explore how a combination of analytic and semantic modelling techniques can be used to support the evolution of networked communities. This support relies, in first place, on enabling more informed decisions based on the identification of social patterns and particularly on the combination of information about topical (or thematic) and personal dynamics in the network.

Social network analysis is an established method to derive person-person relations in the form of sociograms from "traces" of communication in a networked community (cf. Wassermann & Faust 1994). Given the typical types of communication in community portals or forums, it is possible to relate the communication events also to specific topics which, in turn, can be associated with each other through an ontology (i.e. an explicit description of relevant concepts and their relations within a specific domain). Here, the ontology is an intellectual construct given a priori, whereas the sociogram results from an empirical analysis. Semantic background knowledge can be used to suggest additional interactions (e.g., of type "person A should talk to B") based on an ontology link (cf. Malzahn et al. 2005b). On the other hand, personal proximities which are not accounted for by the ontology may indicate an update of the semantic structure.

Our approach is exemplified with a community of practice in the field of technology enhanced learning (TEL), namely the Kaleidoscope Network of Excellence. The methodology has been originally developed and implemented in an interdisciplinary research project on "Virtual Work and Learning in Project Based Networks" (VIP-NET project no. 01HU0128, cf. Malzahn et al., 2005a). The FreeStyler application, a mind tool focusing on collaborative modelling and simulation, which has a direct interface to the CoNaVi application (Community Navigation Visualizer; see Malzahn et al., 2005b) provides an easy-to-use interface to these methods. It can be applied to various networked communities, such as learning communities and/or communities of practice, and makes use of different types of input data.

Use Cases and Methods of SNA for Community Support

In the following subsections we will define the basic issues of classic Social Network Analysis and then introduce our ideas for enhancing the community support by means of enriched SNA techniques. We will present the stimulation of new partnerships between network actors by the augmentation of social networks with semantic networks. The evolvement of a community goes hand in hand with the development of the conceptual framework of it. Therefore we propose an SNA based approach for the detection of conceptual changes (Slotta, Chi, & Joram, 1995) on community level. The liveliness of a community is influenced to a large extent by the trends that define the major strands of interest. We present several techniques how to spot trends to support communities in their evolution and self-reflection.

Bi-partite social networks of actors and topics

The data that networks can be built upon and the analyses that can be conducted are manifold. Social Network Analysis (or SNA, see Wassermann & Faust, 1994) relies usually on homogenous networks with one type of actors, namely persons, that are also called one-mode-networks. In these networks specific properties, such as centrality or prestige of a person or the overall centralization and density of a network can be computed by well-defined formulae.

Yet computer-supported interaction and cooperation typically involves mediating artefacts, such as written documents like emails or postings as well as diagrams or models being co-constructed by a group of learners. These "tangible" products can be seen as another type of entity to be included in the network. Exchange on the level of the original artefacts can also be provided by similarity-based search in a shared collection of objects (cf. Hoppe et al., 2005). If we restrict our analysis, in this sense, to "communication through artefacts" (Dix et al., 2004) this will result in networks only with relations spanning between elements of the two different categories (i.e. person-artefact). This network structure corresponds to the one of a bi-partite graph. Typical examples of these kinds of relations are, e.g., a person creating, deleting or modifying an artefact (cf. Ogata & Yano, 1998) such as a forum posting, or a person expressing interest in an artefact, such as subscribing to a thread or discussion board. In a generalization step, an artefact can be classified by its semantic content or theme. E.g., all forum postings classified under "SNA in CSCL" would be seen as related to one topic or theme. This would potentially reduce the number of non-person nodes from artefacts (postings) to topics and increase the number of persons gathered around one topic (as compared to the original postings). Similar bi-partite networks have been discussed in SNA under the notion of "affiliation networks" (Wassermann & Faust, 1994).

These networks provide the potential for a variety of analytical approaches and applications: Persons might be interested in other persons related to an object of their interest, to contact them for discussion and exchange; a researcher might be interested in relations between topics that have been created indirectly by people related to these topics indicating possible connectedness of the topics. These kind of mathematically inferred topic-topic-networks are called event overlap networks (Breiger, 1974) in the SNA literature.

In the following subsections we will discuss different use cases for SNA-based community support and explain the methods that facilitate this kind of support.

Team recommendation - Enriching bi-partite networks with expert knowledge

The example mentioned above of people being interested in other persons related to an object of their interest can be considered the computation of the path length 2 in the simplest case, i.e. the multiplication of the network matrix with itself. In bi-partite networks this will result in either person-person or topic-topic networks, i.e. one-mode networks that can be analysed further in the usual way. These strict networks structures might be interesting for analytical purposes, but have the danger of producing either already known or rather trivial insights: Imagine a member of a University's discussion network who participates in one specific discussion board; the computation of the person-person network will show him the people that he already saw in the discussion thread, thus not giving him information about further discussion partners.

A more interesting information could be the persons participating in a discussion thread that is related in some way to the thread he is interested in. This could be inferred by the creation of a topic-topic network, as discussed above, or by the explicit additional information about topics represented as a knowledge map, which tends to be available often through an expert (e.g. the moderator of the forum) or a shared conceptualisation, also known as an ontology (Gruber, 1993). Using this explicit additional information together with the bi-partite network results in a network structure that is no longer a bi-partite network, since nodes of the same type might have relations with each other. A schema for this combination of *bi-partite networks* with a *knowledge map* into a *multi-mode network* can be seen in figure 1.

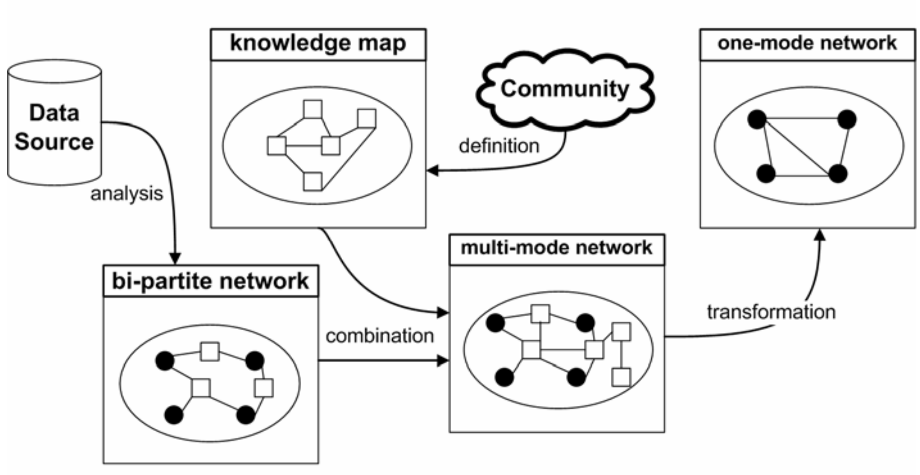

Figure 1: Schema for the augmentation of bi-partite networks with knowledge maps

This affords a different kind of computational method than the standard ones for affiliation networks that we call *ontology-facilitated navigation* and that is described in detail in (Malzahn et al., 2005b). Using weighted and typed relations in the additional ontology, the multi-mode network is transformed into a one-mode network (see figure 1 top right), which contains relations that was mediated only by the information expressed in the ontology. In our example of the discussion board, the student would get information about the persons involved in a separate thread she might not have been aware of, but that is relevant to her area of interest, instead of getting information about the persons she already knows. Since experiences with expert and diagnosis systems showed that users want to have explanations (Clancey, 1983) of computed results we decided to enable the user to color the relations between the topics in the ontology. The colors used in the ontology are then transferred to the resulting person-person network so that the user can identify the relations and therefore the artefacts that have led to the computed relation. Along the way the user gets the information how many different ways facilitate the relations because every color represents another path from one person to the other. This kind of information produced by our method of combining bi-partite networks with networks based on expert knowledge is mainly interesting for the future behavior of the user e.g. by contacting the newly identified persons for discussion about their joint interest. Thus the inferred network information might be used to recommend options and consequently evolve communities towards new kinds of relations.

Reconciling, evolving and validating community terms using SNA

In the previous section we have shown that ontologies are valuable tools to foster relations that might not be obvious to the majority of participants in a community. In this section we want to show how social network analysis can be used to validate presumed relations between artefacts in the observed community. When communities come into existence they usually develop their own vocabulary and standards (cf. Wenger, 1999; Zeini, 2005). This is done either implicitly by using the same terms for the same concept or explicitly by developing an external representation of their common understanding. Sometimes even the vocabulary itself is the object of common interest. This is e.g. the case with the notion of *collaboration script* in CSCL. A lively community will adapt itself to new developments in their field of interest. So should the ontology enable all members of the community to profit from new insights. The adaption will most likely manifest itself by the integration of new members into the community or by the re-orientation of - in the beginning some members of the community towards new topics (or artefacts) of interest. Sometimes this process is made very explicit by those people by announcing the next big issues and grand challenges (such as in Hoare & Milner, 2004) for a community, but most of the time the change is made silently and unnoticed by the community: there are persons who work on topics of two seemingly not connected topics - at least in terms of the agreed on knowledge map. If more and more people work on two topics not connected in the map the community should investigate these two topics concerning the nature of the link. This provides deeper insight in the topic and might strengthen a new research field.

Social network analysis can support the community by highlighting missing links, confirm existing links or even questioning presumably existing links in the community's ontology. We use a weighted and standardized co-occurrence algorithm based on actors' relationships results in a network of artefacts that can be compared to the existing knowledge map. The resulting network distinguishes three types of relations in the reconciled map:

- *green relations* indicating that these relations were confirmed by the affiliation network, i.e. they are part of the given map and various persons are working on both topics.
- *red relations* indicating that these relations could not be confirmed by the affiliation network, i.e. they are part of the map but no one is working on both topics.
- *grey relations* indicating that these relations are emerging from the network, but they are currently not included in the map.

All three types of relations are valuable for the community. Although the green ones may seem to be trivial because they are already known, they confirm the validity of the given ontology. The red ones are important because the observer might want to investigate if either the ontology has to be corrected because the currently existing relation is not valid (anymore) the e.g. in research networks the combination of topics is so well-established and researched that further work is not spent. The most promising consequences might be drawn from the grey relations. These relations may indicate missing links in the ontology. If there are strong ties between two topics because of the amount or the reputation of the persons working on both topics the observer should carefully consider the inclusion of this link into the common knowledge of the community. So the analysis of relations between actors and topics can be used to evolve the common grounding of a community.

Trendspotting - identifying topics of interest in a network

Innovation and also research in and for the information society are to some extent driven by the emergence of new topics and trends. To identify these trends early is an important success factor. In science and research this corresponds to the identification of big issues and grand challenges (Hoare & Milner, 2004). In the commercial world, the dynamics of life-long-learning is driven by such trends. Personal and public communication can be a source of knowledge about trends. Similarly it is valuable to identify persons that are known to be trendsetters or early adopters of technology (Rogers, 1995). We propose to apply SNA-based techniques to support the identification of trends (“trend-spotting”) and suggest two related approaches:

Trend analysis via temporal dimension

A trend is usually associated with a new term or label coming up in the communication within a community. Thus, investigating changes in terminology over time can give an indication of the trends in a given field. For our approach of conceptualizing scientific and learning communities as multi-mode networks interacting around specific topics and artefacts, the changes in the network over time are the indicator for trends: on the one hand the differences within the network at specific points in time are important, on the other hand the relations that span across a time period give additional insights. This means that for our network analyses we consider the comparison between different "snapshots" of the network, preferrably at well-defined moments, such as the beginning of a new period (e.g. a new year at university, a new period of funding for projects). Basically, entities and relations in the network could have persevered unchanged, emerged newly, or vanished. This information can be combined with relations over time that express the change or influence of a network element. This information enriches the plain information of differences, since it reflects also the potential change and evolution of persons, artefacts, or relations in a network. These phenomena in the network can be indicators for trends. They can be further operationalized with SNA methods by considering network properties, such as density of the network or centrality of a topic, in the perspective of their temporal change. An example for our approach of identifying trends in a network according to the temporal perspective will be given in the example section of this paper.

Trend analysis via trusted authorities

Another approach to identifying trends is to look at suspected trend setters or early adopters (cf. Rogers, 1995). These persons are usually considered as trusted authorities because of their expertise or influence on the community. It is not important that all members agree on a fixed set of authorities because this type of trend spotting relies on trust and beliefs. It is therefore bound to the personal judgement rather than a general agreement, although agreement may help to build up trust.

Accordingly, trends can be detected by examining the surrounding of such a trusted authority, i.e. the topics or persons the authority has recently established links with. This can be supported using visual navigation through the community networks by providing means to find authorities and focus on their neighborhood in a flexible way, e.g. by varying the degree of shown details.

Example - the Scientific Network Kaleidoscope in Technology-Enhanced Learning

As a proof of concept of our methods for fostering communities we chose the Kaleidoscope Network of Excellence (IST 507838). Kaleidoscope is a scientific network with institutions from academia and industry in the area of Technology Enhanced Learning (TEL). It brings together persons and teams from multiple fields of expertise and aims at the integration of concepts, institutions, and technology to strengthen the ties in the European research area. All in all Kaleidoscope consists currently of approximately 80 partner institutions and 1000 personal members of all old member states and several new member states of the European Union. Because of its size the Kaleidoscope network has a more complex structure than the usual two-mode networks discussed in the previous section. Kaleidoscope has a strong sub-community (Special Interest Group = SIG) interested in Computer-Supported Collaborative Learning, that has approximately 380 participants. For our analyses we will focus mainly on this community to identify major strands of work and recent trends of this European CSCL interest group. As formally captured data for the bi-partite networks we use the authorship of reports / deliverables within Kaleidoscope: a partner institution is connected to a Kaleidoscope activity if it is one of the contributors of a report. The resulting network of figure 2 is thus similar to a co-citation network. The labels “Dxx” in the boxes represent the work package numbers of the different activities. The small ellipsoids represent some of the teams that are part of Kaleidoscope.

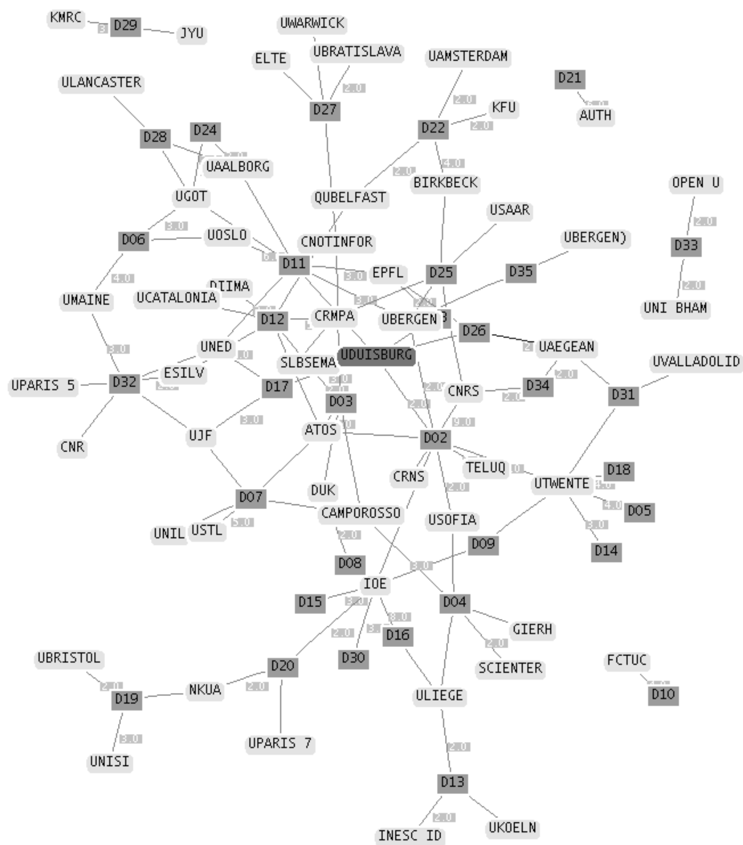

Figure 2: Bi-partite Team Deliverable Network

Team recommendation and network mapping

When applying the standard operations of transforming the bi-partite network to a one-mode network (Wassermann & Faust, 1994), the collaboration between teams can be identified easily. While this is interesting for analytical purposes, it is not enough for creating substantial recommendations for the future, i.e. for community building activities, because these connections should be obvious for all the actors involved directly.

For the recommendation of non-trivial links in order to promote community building we extend conventional social network analysis with the following approach: Using either a personally created conceptualisation (personal view) of the field or by applying the shared conceptualisation of the community (ontology, cf. Gruber, 1993) in combination with the bi-partite network, a weighted network can be created for recommendation of links. The algorithmic details of this approach have been presented in Malzahn et al. (2005b). In our example case we applied the *knowledge map* of our team’s personal view on Kaleidoscope's activities to the *bi-partite* authoring network to search for partners with similar interest. Because of the nature of the selected data set not all of the links that our team established during the past are part of the data. This is because some teams did not formally submit a deliverable (viz. not being a main author) for every activity they were participating in. So some of the links are missing and we can evaluate our link recommendation method by evaluating if these missing links are found. We created a knowledge map representing our team's view (cf. figure 3) of Kaleidoscope's activity interrelations with the help of the FreeStyler application in combination with CoNaVi.

The team’s perspective (knowledge map) on the Kaleidoscope network was then applied to the bi-partite network shown in figure 2. Our extended SNA approach indicates that there are links of interest between our team and other partners in Kaleidoscope as shown in the resulting one-mode network in figure 4 that have not been present in figure 2.

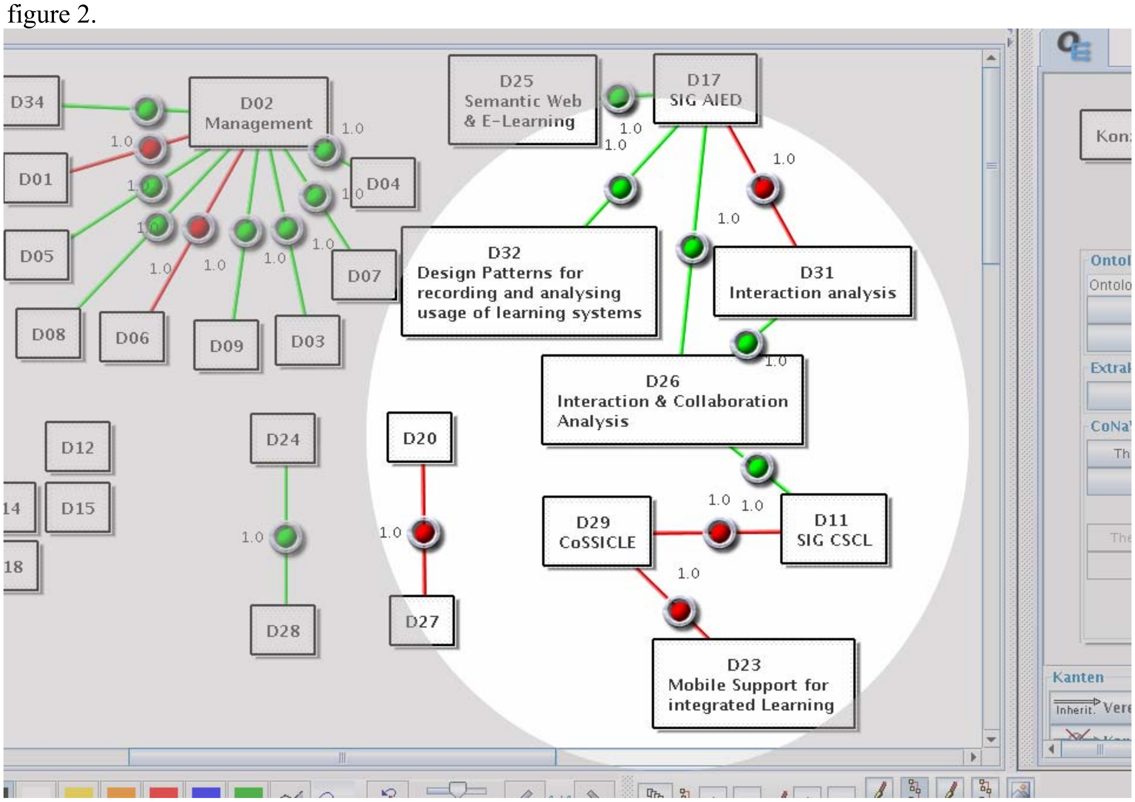

Figure 3: Manually created knowledge map of our team’s perspective on the activities

Looking at the set of proposed new partners we clearly realized that the algorithm was working plausibly because with some of the partners we were already in touch. Since the given data was not representing all of our activities in Kaleidoscope the algorithm could not take into account those links from the beginning. This kind of validation of the learned links is quite similar to the commonly used "leave one out" cross-validation approach in machine learning. The really new links motivated us to have a closer look at these Kaleidoscope partners’ work, the type of usage we designed this approach for. Admittedly we discarded some of the links again, but in the end we were stimulated by the algorithm's results to communicate through the artefact by reading their papers - which is in turn valuable for a community like Kaleidoscope because it generates a deeper understanding of the whole field of TEL.

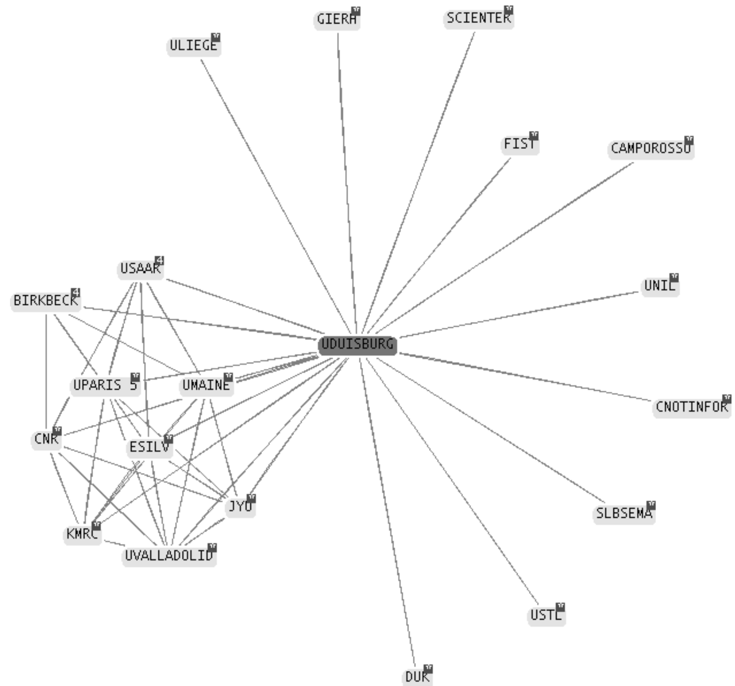

Figure 4: One-mode network with teams linked to our team after ontology facilitation

Trend-spotting via trusted authorities

To demonstrate the method of trend-spotting via trusted authorities described generally in section Trend-spotting we assume that the user regards our team as a trusted authority for promising research topics. If this person analyses Kaleidoscope network with CoNaVi he or she would notice that UDuisburg is currently involved in five activities (see figure 5). These activities are marked with numbers indicating the amount of other teams involved in the corresponding activity. Considering his or her own interests and links towards certain topics the user is now able to investigate one of the topics further. Given that the user is currently not involved in mobile learning activities and discovers that UDuisburg is involved in such activities he might take participation in mobile learning activities into consideration, if he thinks it is a promising direction based on his trust in the supposed authority.

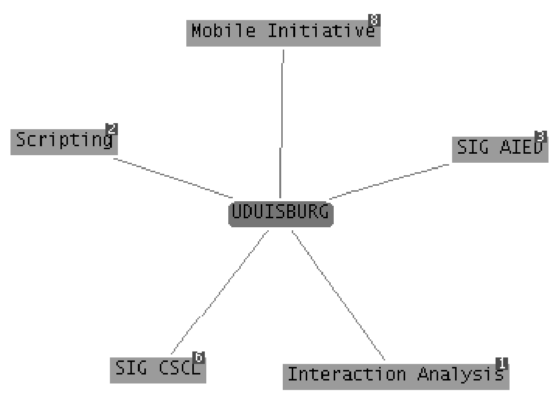

Figure 5: Looking at the scope of interest of a trusted authority

Trend-spotting in Kaleidoscope - a temporal perspective

Since the Kaleidoscope network renews its activity plan each year, a temporal shift of activities which might reflect trends and evolution within the network is an interesting issue for analysis and also for the strategic orientation towards the future. Kaleidoscope is currently in its third year period, thus we can refer to the data from 2 finished work programs and its extrapolation to the third year.

To highlight the evolution of the research network according to new research lines and changes of focus, we show the changes in the activities from one period to its succeeding period. Figure 6 shows the changes from Year 2 to Year 3.

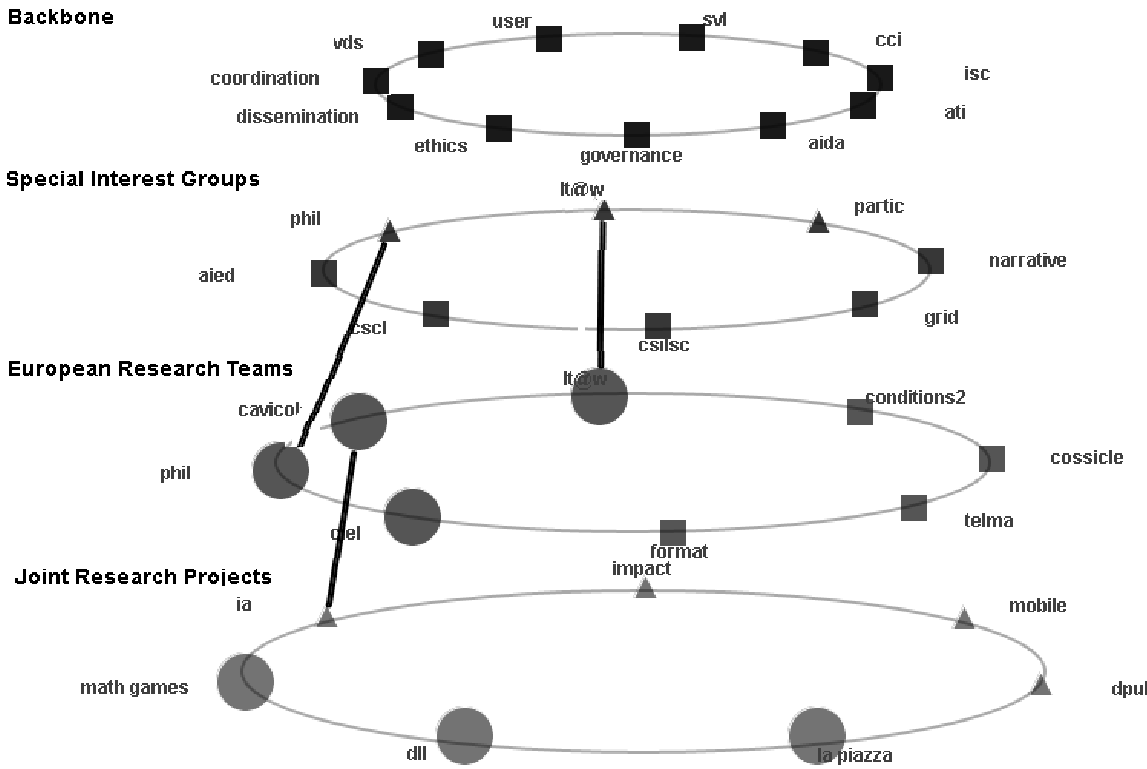

Figure 6: Evolution of Kaleidoscope from Year 2 to Year 3

Activities that have been continued in the same format from one year to the other are represented as middle-sized cubes; the dynamic evolution of the network can be seen in activities, that have been discontinued at the transition from one period to the next (represented as small cones), and activities that started in the new period, which are represented as large spheres. Especially interesting are the transformations from short-term activities, such as Joint Projects with duration of one year, into activities with a longer-term perspective, mainly Research Teams that are planned to be sustainable for a longer period. These direct transformations are shown as links between activities from one year to another, i.e. from a cone to a sphere. The figure shows that one of Kaleidoscope's major concerns is the evolution into a reliable and sustainable structure reflecting major research areas as well as current trends of Technology Enhanced Learning.. This is especially visible in the number of Research Teams that grows from four in year 1 to eight in year 3.

In a complimentary analysis we extracted current trends in the Kaleidoscope CSCL community. First we identified the Kaleidoscope teams with a strong participation ratio with respect to CSCL: We only considered teams with at least 50% of their team members being also members in the CSCL Special Interest Group. This threshold was validated with the computation of the median of teams, which resulted also exactly at a ratio of 50%. Then we identified the new Kaleidoscope activities that the “CSCL” teams have participated in since the year 2006 as an indicator for recent projects that might have emerged with CSCL aspects in mind. The activities that resulted from the combination of statistical analysis and the new bi-partite network are:

- *Learning Patterns for the design and deployment of Mathematical Games*, which supports the collaborative design of educational games by collecting re-usable patterns for mathematical games.
- *Integrating Collaborative, Inquiry and Experiential Learning* which brings together the strands of experiential and inquiry learning with collaborative learning, thus creating for the students rich learning experiences with scientific methods in a social context.

- *Computer-based Analysis and Visualization of Collaborative Learning Activities* which that aims at the integration of computer-based methods into the analysis process of collaborative activities by means of capturing, processing, and visualization the collaboration.

Indeed all these activities have a CSCL tint, which can be interpreted twofold: on the one hand the CSCL community can be considered an important driving force for the Kaleidoscope network, on the other hand these topics may be potential trends for CSCL research also on a broader scope. Some of these analysis results might have been obvious to or at least assumed by people involved in the Kaleidoscope network, yet the social network approach can be used to assure these assumptions by using the SNA inspired measures that can be easily derived from the given data by our tools. In addition non-evident links from activities can be identified and be used for new collaboration opportunities between the projects.

Discussion - Privacy Issues and Implications on Visualization

Experiences from the research project 'VIP-NET - Virtual Work and Learning in Project Based Networks' led us to the conclusion that personal networks can sometimes be critical for analysis purposes. Some people disagree with the idea of opening their personal networks for scientific analysis, since these networks represent their social capital. On the other hand these people are often interested to explore their personal networks to exploit them more thoroughly. Another example where information may be affected by privacy issues is in the case of teaching. In (Harrer et al., 2005) for example we had to anonymize the results for the publication. For teachers it could also be problematic when external people (e.g. social network researchers) see the structural data of classroom activities, since there may be some students who are not as well integrated in the class as others.

These privacy aspects related to personal networks led us to the question how to support users to explore their own networks using social network analysis techniques. Our approach addressing the operationalization of social network analysis for non scientific users is to embed advanced measurements into the visualization. According to (Krempel, 2005) techniques exist to integrate structural properties of networks in the display. For this purpose we created the Weaver application, a 3D visualizer for social networks, which arranges and draws the nodes according to properties such as degree, centrality, or externally defined properties within a simple solution space. From the user view this means, that he or she is able to perceive the properties of a node immediately (e.g. what is the most central topic in the network). The figures 5 and 6 show nodes arranged by their type and shaped by additional information on their life-span.

Conclusions

This paper presented three approaches (team recommendation, knowledge map evolution, trend spotting), on how to gain information with SNA-related techniques in multi-mode networks. We showed how our tools can support different use cases of community support: CoNaVi in combination with FreeStyler enables its users to visualize and navigate through (enriched) multi-mode networks as well as evolve given knowledge maps with the help of empirical data. Weaver's hierarchical views and filters allow for emphasizing temporal developments for trend spotting.

The proposed methods for fostering new personal links rely on the mathematical properties characterizing the structure of the network data. The approach dealing with trend-spotting uses a sociometrically inspired technique to enable the user to reflect on the current state and temporal evolution of the examined network providing a foundation to develop a strategy for self-development and/or re-positioning in the community. A typical use-case of trend-analysis is the support of freelancers. They have a constant need to discover potential trends in technology to be up-to-date for the next contract. Albeit we focused on a scientific community for our analyses because its rich structure provides a good demonstrator and testbed for our approaches, we think that the support is not limited to this kind of community, but can be applied as well for learning communities, especially the ones with computer-based learning support. Almost all universities provide forums accompanying the courses to exchange ideas and provide help for the students having either a problem within the current topics or with organizational issues.New users tend to cross-post their questions in several forums to be sure to find someone who answers to the problem. The proposed method about new personal links can be applied here to direct the novices directly to competent helpers. In Harrer et al. (2005) we combined SNA methods on a student community in a blended learning scenario with qualitative and statistical methods. In this earlier work we restricted our approach to the analytical perspective without giving feedback to the students on their network position. In upcoming courses we plan to combine the use of analysis feedback as sketched in Daradoumis et al. (2004) with our techniques of community support by directly giving feedback and recommendation.

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Conceptual and Computational Issues in the Formalization of Collaboration Scripts

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Abstract: Collaboration scripts aim at facilitating social and cognitive processes of collaborative learning by shaping the way learners interact with each other. Computer-supported collaboration scripts generally suffer from the problem of being restrained to a specific learning platform and learning context. Researchers are therefore aiming for a formalization of collaboration scripts on both a conceptual and a computational level. A recently developed framework allows to describe collaboration scripts using a small number of components (participants, activities, roles, resources and groups) and mechanisms (task distribution, group formation and sequencing). Based on these, a formal, graphical modelling tool has been developed and tested with several example scripts.

Introduction

Collaboration scripts are based upon the scripted cooperation approach, originally developed by O'Donnell, Dansereau, Hall and Rocklin (1987), which differs from other collaborative learning approaches in that it aims at facilitating social and cognitive processes of the learners by means of providing a carefully designed structure for small group interaction. Collaboration scripts have become fairly popular within educational science, especially in the domain of computer-supported collaborative learning (CSCL), where they have been used in various settings, including face-to-face, web-based as well as mobile contexts. So far, collaboration scripts are hardwired to a specific learning environment and context, limiting their portability, scalability and adaptability as well as making it difficult to research the specific effects of scripts on learning processes and outcomes. In order to resolve these issues, researchers aim for a formalization of scripts both on a conceptual and a computational level.

The current de facto standard for the specification of executable learning processes is IMS Learning Design (IMS/LD) (Koper and Tattersall, 2005). The editing level of IMS/LD is mainly a textual that is close to the technical specification: there are some (mostly) tree based editors, which try to abstract from the XML-based language, but there is no "native" graphical representation. The suitability for formalization of complex collaborative learning scenarios has been critically discussed in the CSCL area (Hernandez et al., 2004; Miao et al., 2005), which might imply that for the CSCL researcher an adapted and specialized conceptual model with explicit concepts like groups and dynamic assignment of resources is needed.

As a conceptual and computational formalization goes hand in hand, this task was recently approached by an interdisciplinary research team of computer scientists, psychologists and educational scientists, leading to a common framework for the specification of scripts (Kobbe et al., subm.). Consolidating the conceptual analyses of Dillenbourg (2002), Dillenbourg and Jermann (in press) and Kollar, Fischer and Hesse (in press) with new insights into the composition of scripts, the specification proposes a comprehensive yet economic description of collaboration scripts, featuring five basic components and three basic mechanisms. The components include the individuals that participate in a script (*participants*), the *activities* that they engage in, the *roles* they assume, the *resources* that they make use of and the *groups* they form. Script mechanisms help to describe the distributed nature of scripts, that is, how activities, roles and resources are distributed across participants (*task distribution*), how participants are distributed across groups (*group formation*) and how both components and groups are distributed over time (*sequencing*).

Based on these components and mechanisms, we have started to develop a tool for the formal, graphical modelling of scripts. A formal, graphical model combines the advantages of computer-readable, formal data structures for issues of portability, scalability and adaptability with those of graphical representations: A graphical model usually is much easier to read and analyze (Shu, 1998), in particular by non-computer-scientists whose judgement and input is indispensible for the conceptual validation of the computational model. Furthermore, some features of collaboration scripts are best conveyed graphically, such as parallel activities, repetitions, and conditional branches. And last but not least, a graphical modelling tool serves as a prototypical authoring environment for the design of new collaboration scripts. To a target user group of educational researchers and practitioners with little programming knowledge, a graphical authoring tool will be much more user-friendly than a programming editor.

Modelling Scripts

Today, a large variety of highly sophisticated graphical notation systems especially in computer science exist. Yet none of these have found to be fully appropriate for the modelling of collaboration scripts (Harrer & Malzahn, 2006). Inspired by the semantics of statecharts diagrams, we have developed a graphical notation which allows a formal modelling of collaboration scripts based on the conceptual framework mentioned above. Since the framework concepts are familiar to the CSCL researcher, we decided to provide a graphical construct for each of the theory based concepts. The components are represented by iconic objects while the dynamic aspects (i. e. the mechanisms) are represented as links between these objects. The inscription of the links is used to define the mechanim more specifically, such as different group formation strategies (e. g. by group size, by number of groups, or by values attributed to the participants, like gender or skills). This direct mapping from conceptual to computational level is further supported by syntactical constraints imposed by the editing tool.

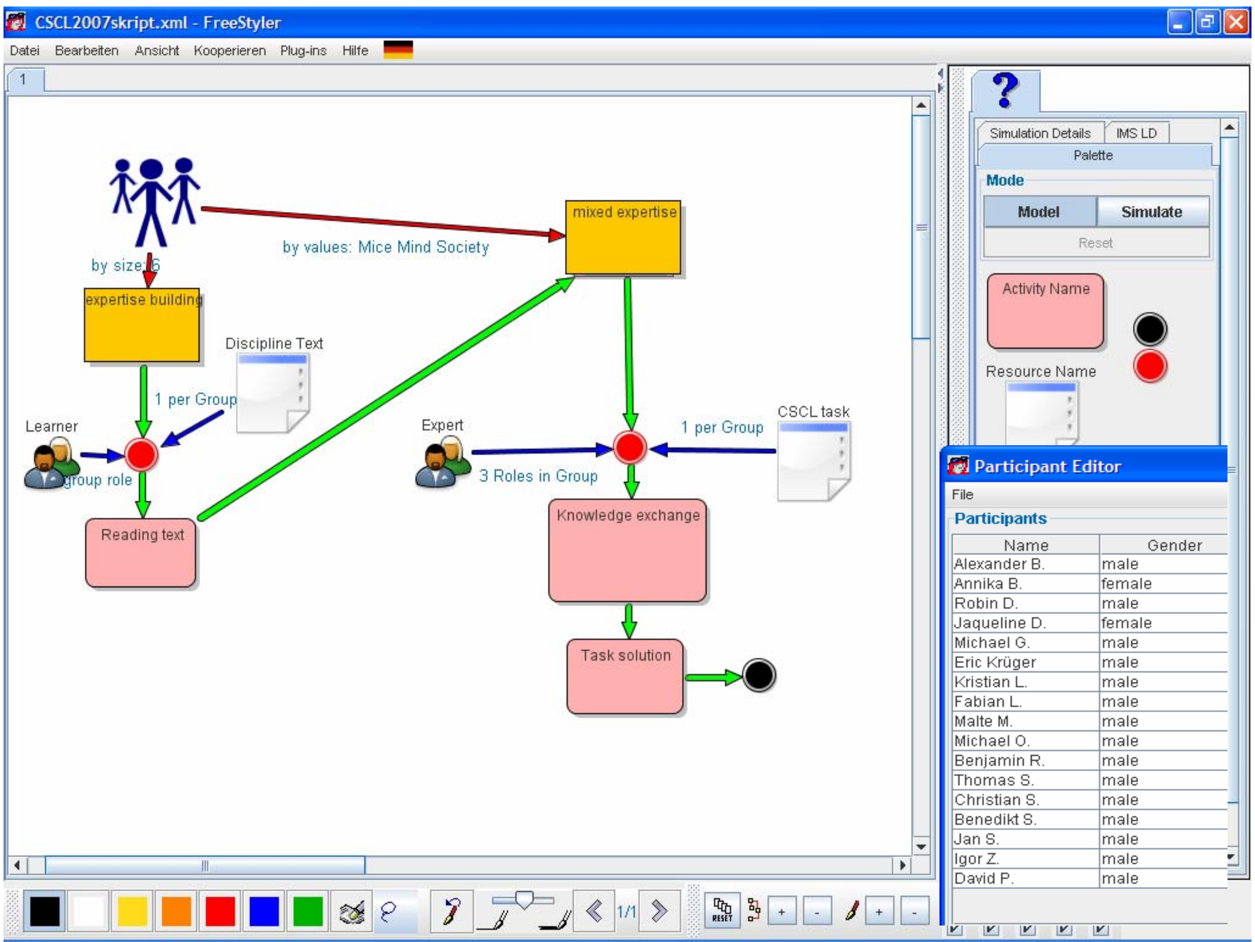

Figure 1. Jigsaw script modelled with the proposed graphical modelling language in the editing tool.

The first prototype we developed was tested with several scripts from the literature to show the soundness of our integrated approach. As an example and to introduce the constructs of the modelling language, figure 1 shows a graphical model of a Jigsaw classroom scenario (Aronson et al., 1978). The participants, symbolized by a group of people, are split into groups of six to study together a text which is characteristic for one the disciplines with respect to CSCL (technology, cognition, society) that they are supposed to become an expert of. The assignment of the text to the particular groups is represented by the iconic document associated to the graphical learning flow (green arrows) with red circles. Since all of the students are on equal footing, they are all learners in this phase of the script. So they are assigned the role *Learner* for this part of the script. The reddish boxes with rounded edges on the end of the sequencing (i.e. the learning flow) arrows represent the activity to be conducted by the groups. After reading the text, all participants are reorganized (red arrow) to form groups of mixed expertise. Each of the groups consists of three members with one from each of the expert groups before. This is stated by the inscription *by value Mice Mind Society* on the red arrow and refers to attributes gained by the resource assignment in the previous assignment. A similar attribution with roles would have also been possible if we had distinguished more than one role before. Finally, the mixed expert groups exchange their discipline specific knowledge within their groups and solve the task that could not be solved otherwise. Thus, the script comes to an end which is symbolized by the black circle.

Conclusions

The presented graphical modelling language based on a theoretical framework addresses CSCL's particular needs for dynamic group formation and role assignment. Thereby it allows the non-computer scientists to model the scripts using an iconic expression level without losing conceptual soundness of the approach. This enables researchers and practitioners to use the model in several ways (Miao et al., 2005): planning, refinement, discussion and exchange of models with peers and students to improve the overall performance of learning. The soundness of the modelling language was tested by several researchers of CSCL, asking them to model their favourite scripts as well as observing a teacher modelling her lesson design with the tool.

In our current work, we are extending our tool so that the models can be simulated in the editing tool and an export to IMS/LD is possible. This will improve the quality of CSCL scripts and learning process further because potential (static) problems with the script can be more easily detected and even dynamic problems can be analyzed by "what-if" analyses. An example for this is the detection of group formations that are not fully compliant to the specified formation strategy, such as distributing 17 students to groups of size 6. This will be detected automatically by the simulation and will be highlighted to the designer of the learning activity. The IMS/LD export will enable novices in IMS/LD to create and configure computer-supported learning scenarios using de-facto standard tools available in the LD developer community, yet modelling in a high-level graphical modelling language using the more convenient conceptual model of CSCL scripts.

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Towards a Flexible Model for Computer-based Analysis and Visualization of Collaborative Learning Activities

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Abstract: The definition of appropriate interaction analysis methods is a major research topic in Computer Supported Collaborative Learning. Analysis methods can be totally or partially supported by computer-based tools that provide for better and more efficient analysis processes. The current research in this field shows that most interaction analysis tools have been based on unstable prototypes, and are highly dependant on the learning environments and research goals for which they were defined. As a consequence, it is not possible to use them in authentic CSCL settings with real users. The goal of this European Research Team therefore is to utilize the synergies of experience in manual interaction analysis with computer-based analytical methods. In this article we present an approach that embeds standardized computer-supported techniques into a semi-formal analysis process model which can be utilized and adapted in a flexible way according to the cases and environments to be analysed.

Introduction

The definition of appropriate interaction analysis methods is a major research topic in Computer Supported Collaborative Learning (CSCL). These analysis methods support the understanding of collaborative learning activities. Such an understanding is the basis for those functionalities that might be offered by an enhanced CSCL environment, including, for example support for students' and teachers' self-regulation, teachers' supervision tasks, the generation of feedback and the design of instructional support measures for enhancing collaboration skills, as well as the assessment of learning experiences and further data gathering. All these functionalities are important for the design of enhanced learning environments that go beyond the communication and information sharing support that current CSCL tools provide.

Analysis methods can be totally or partially supported by computer-based tools that provide for better and more efficient analysis processes. The definition of these computer-supported analysis tools is attracting more and more researchers, but current research in the field is mainly based on unstable prototypes applied to isolated experiences (Soller, Martínez, Jermann, & Muehlenbrock, 2005). As these prototypes are usually not designed for general use beyond the scope of a given research project, their usability is normally very low. Therefore, it is necessary to work on analysis tools that can be applied easily by different real users in different authentic collaborative learning settings. This entails also the cooperation between researchers in collaborative learning and computer scientists in reifying the expertise of human analysts as computational representations.

The overall aim for elaborating an analysis process model common to researchers in the field of CSCL is to reach a higher degree of generalization and comparability. Such a common framework would support the integrated analysis and the standardized exchange of data across analysis methods, tools, research teams, and learning environments. In addition, such a standard analysis process model would enable us to systematically compare the outcomes of individual studies as well as the research models themselves in order to improve the research design. Still, the proposed framework is intended to be flexible enough as to consider qualitative and contextual differences of individual research groups.

The CAViCoLA Process Model

The common analysis process model has been derived from four empirical research designs which have been conducted by four different research groups in Germany, Greece and Spain (Martinez, Dimitriadis, Gómez-Sánchez, Rubia-Avi, Jorrín-Abellán & Marcos, 2006; Meier, Spada & Rummel, accepted; Harrer, Zeini & Pinkwart, 2006b), one of them conjointly between two research teams (Harrer, Kahrimanis, Zeini, Bollen & Avouris, 2006a).

These teams collaborated on the conceptual and technical integration of their research approaches in the European Research Team “Computer-based Analysis and Visualization of Collaborative Learning Activities”(CAViCoLA) within the Kaleidoscope research network. A graphical overview of the combination of different analysis methods and their facilitation by a unified data format (CAViCoLA Common Format) can be seen in Figure 1.

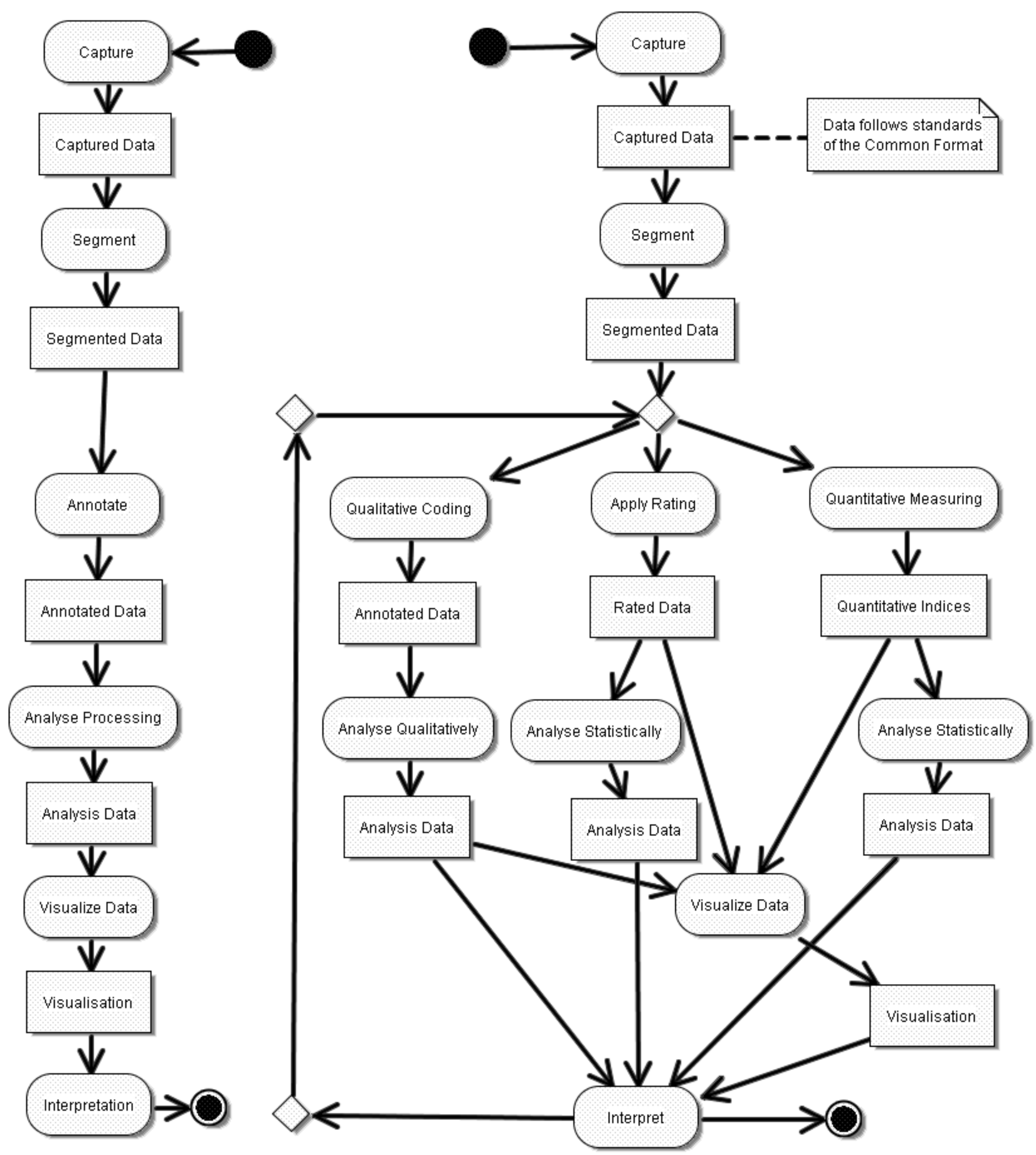

Figure 1: Graphical Representation of the CAViCoLA Process Model

The left side of figure 1 shows the generic process sequence used within the European Research Team. On the right side the CAViCoLA process model combines several quantitative approaches, such as interaction analysis of the participants’ actions in time, analysis of group structures in learning communities (Social Network Analysis and statistics; Harrer et al., 2006b; Martinez et al., 2006), and a rating scheme for assessing the quality of the collaboration process (Meier et al., accepted). This is complemented by qualitative methods, such as content analysis, observations, questionnaires, focus groups and category building (Harrer et al., 2006a; Martinez, 2006). All these analysis methods follow the classical procedure of *data capturing*, *data segmentation*, *preprocessing* (e.g. annotation and measuring), qualitative, statistical and social network *analysis*, and potentially *visualization* to support *interpretation*(see left). The overall approach follows the classical idea of the triangulation of results

(Denzin, 1980) that is visible in the different analysis paths in the right side of fig. 1. Since the interpretation of the research findings is important in the refinement of the process model, the feedback loops facilitate the incremental aspect of the model, such as the iterative cycle process within Grounded Theory (Strauss & Corbin,1990) for qualitative approaches or the building of indices (Inglehardt, 1977) for quantitative designs. For example, the annotation process described in Harrer et al. (2006a) is based on iterations from open coding to annotating data, which was focused on related studies (e.g. Gunawardena, Lowe & Anderson 1997) and internal discussions between the research teams in Germany and Greece.

To facilitate the flexible combination of different analysis tools during the process, we defined a standardized data format that captures the relevant information of collaborative learning activities. This allows the analysis of several types of captured data, such as the different learning environments used by the partners, e.g. Synergo (http://www.synergo.gr), FreeStyler (http://www.collide.info), Discussion Forums (e.g. phpBB), BSCL-Synergeia shared workspaces (http://bscl.fit.fraunhofer.de/), with the same interoperable set of analysis tools. Among these analysis tools are applications for the qualitative coding of observation data captured by video, for the generation of logfiles capturing user interactions in CSCL systems, and for gathering sociometric data. The logfiles captured are also used for replaying, interpreting, and annotating collaborative workspace activities: this has been done in previous research of the partners and is currently used in the European research project ARGUNAUT that uses the standardized data format to support the moderator of electronic discussions in analysis and annotation.

Perspectives

In future work we plan to conduct multilateral and cross-national studies between the partner sites that will use the proposed analysis model for CSCL activities and take advantage of the standardized data format for interoperable and flexible usage of diverse analysis tools. This will also facilitate further evaluation of the model that can lead to its further refinement. Some phases of the model, like the analysis and visualization phases which depend on the interoperability of tools that provide automated analyses, can also be further formalized in more detail. For instance we are working on approaches for the visualization of the dynamics of social networks and the graphical representation of dimensions of collaborative processes using semantic differentials.

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Collaborative Lesson Analysis in Virtual Groups: The Impact of Video on Student Teachers` Analysis and Reflection Processes

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Abstract: Reflection on teaching experiences is considered to be an important element of teacher training. Given the increase of virtual or partly virtual seminars and related constraints, video is gaining relevance because it facilitates an analysis and reflection on teaching experiences, which is independent of time and place. Research indicates that the use of video-recorded lessons for collaborative analysis in virtual groups has a positive effect on student teachers' reflection processes regarding teaching situations. Following a field study by Ploetzner et al. (2005) on different applications of the learning environment "v-share", we conducted an experimental study to investigate the impact of video on student teachers` analysis and reflection processes in a more controlled way. At the conference the learning environment and our research findings will be presented.

Introduction

The major goal of teacher training is to impart to student teachers the knowledge and abilities necessary to plan, carry out and evaluate teaching. Central to this is the ability to reflect on teaching experiences: student teachers are to relate theoretical concepts to real teaching situations and the underlying pedagogical content knowledge. By distancing themselves from their actions (cf. "reflection-on-action", Schön, 1987) they are able to analyse their teaching and to question their subjective theories. The analysis and reflection of experiences helps students to evaluate their teaching and to develop alternative - and theoretically sustained - instructional strategies for future teaching. With the growing number of online university courses and virtual or partly virtual seminars, the question arises as to how the need for reflection can be met in pre- and in-service teacher education, independent of time and place. On account of the distance between individual student teachers and the lack of time for reflection during face-to-face meetings, this cannot be done by the same means as in traditional face-to-face teacher training. Particularly, virtual groups lack the possibility to reflect cooperatively on shared teaching experiences by getting involved in a focused discussion with lecturers and fellow students.

In recent years several researchers (e.g., Van Es & Sherin, 2002; Petko et al., 2003) have investigated how video-recorded lessons can be used in teacher education to improve teaching skills. Among many other benefits, video is gaining importance because it facilitates analysis and reflection on teaching experiences, independent of time and place. Virtual learning environments like "LessonLab" (www.lessonlab.com) or "v-share" (Ploetzner et al., 2005) have been developed to support the video-based analysis and reflection in virtual groups. Research indicates that the use of video-recorded lessons for collaborative analysis in virtual groups has a positive effect on student teachers' reflection processes regarding teaching situations (e.g., Derry et al., 2002; Santagata et al., in press).

Benefits of Using Video in Teacher Education

Compared to direct lesson observations, the video-based analysis and reflection on teaching experiences has various significant advantages: as a lasting external representation, video recordings enable a flexible and detailed lesson analysis. Video can be played repeatedly, it can be stopped and continued at any time, and moreover, jumping to a certain point in the video makes it possible to view specific scenes. With these options, video serves as an external memory (cf. Keil-Slawik, 2000) and helps to identify aspects, which might otherwise have been unnoticed during direct observation. Furthermore, video allows student teachers to observe and to analyze their teaching without the need for immediate reaction. The temporal separation of teaching and its analysis helps students to distance themselves from their actions and thereby facilitates reflection instead of action.

A special benefit results from the feature of marking certain sequences of a video. This allows student teachers to easily refer to a special part of the recorded lesson, which they otherwise would have to circumscribe verbally. According to Clark' s (1996) theory on achieving common ground in communication, video thus serves as a shared external reference point and makes the process of grounding much easier and less susceptible to faults. In addition, the permanence of video permits one to observe the same lesson several times, focusing each time on a different aspect. This allows the adoption of multiple perspectives on a lesson (Van Es & Sherin, 2002), which is of great importance for the problem-based analysis and reflection on teaching. The theory of cognitive flexibility (Spiro & Jehng, 1990) states that the repetitive study of a subject matter under different perspectives and approaches promotes the acquisition of flexible and deep knowledge. Considering the diversity and complexity of teaching situations, such knowledge plays an important role for prospective teachers. Furthermore, if student teachers reflect cooperatively on shared teaching practices, they have to acknowledge and come to terms with their fellow students` perspectives. According to the socio-constructivist theory of learning (e.g., Doise & Mugny, 1984), student teachers learn from diverse stances by comparing, questioning and explaining them.

Empirical Study

The study investigated the impact of video on student teachers` analysis and reflection processes using "v-share", a program for the cooperative analysis and reflection of video in distributed groups (cf. Ploetzner et al., 2005). The following research questions were addressed: (1) How does the availability of a video-recorded lesson in v-share affect student teachers` analysis and reflection processes? (2) In which aspects does a collaborative video-based analysis differ from a collaborative analysis without video?

Design and Data Analysis

Overall, 30 first-year student teachers with little teaching experience participated in three video analysis sessions. During the first session students were introduced to v-share including how to use the video, to select subsequences of the video, to write contributions and to link them to subsequences of the video. In the second session student teachers watched a short videotaped lesson excerpt on a big screen while focusing their observation on the issue of giving instructions; afterwards they discussed the lesson in distributed groups of three by making use of v-share. All subjects could use the previously seen video in v-share for their analysis. This session served to distribute the subjects into two parallel test groups. For the third session the procedure stayed the same, but the analysis of another lesson now took place under two different conditions: subjects of the test group (video) could make use of the lesson video in v-share as before, while subjects of the control group (non-video) now had to discuss the lesson *without* the video, relying exclusively on written notes and their memories.

Data consisted of student teachers` written analysis and reflection contributions available in the bulletin board of v-share. Applying a coding-and-counting method for quantitative content analysis, the contributions were initially assigned to the following four coding categories, adopted from the field study by Ploetzner et al. (2005):
1. *Describing*, 2. *Explaining*, 3. *Critiquing*, 4. *Proposing Alternatives*. In addition, in order to measure qualitative differences within each category, they were further differentiated by partially adapting Ohlsson`s (1996) taxonomy of epistemic activities. Descriptions and explanations were rated within the dimensions *Particularity*, *Interaction* and *Sequence of Events*. Descriptions were subsequently rated within the dimension *Neutrality*, and explanations within the dimension *Theoretical Concepts*. In both categories each contribution was rated as either positive or negative in each of the four dimensions. Thus the ratings of descriptions and explanations could range from 0-4 and contributions were assigned to one of five levels ranging from low=1 to high=5. Critiques were rated within the dimensions *Number of Arguments* (0, 1, >1) and *Elaboration* (low, high). The combination of both dimensions resulted in a rating matrix whereby critiques were assigned to one of four levels ranging from low=1 to high=4. Similarly, alternatives were rated within the dimensions *Elaboration* (low, high) and *Justification* (none, low, high). The combination of both dimensions resulted in a rating matrix in which alternatives were assigned to one of four levels ranging from low=1 to high=4. Contributions that seemed to be unrelated to the lesson analysis were coded as off-task and were excluded from further interpretation. All data was coded by two independent raters. On a subset of n=116 contributions inter-rater reliability for the coding categories was $\kappa= .79$. On the basis of the corresponding ratings in the coding categories (n=102) inter-rater reliability for the different levels was $r= .76$.

Results and Conclusions

Findings show that student teachers` analysis and reflection were more focused if they could use the video in v-share: on average, video-based analyses were more concise than analyses in the control group (Video: 254 words; Non-Video: 322 words) and contained significantly fewer off-task contributions (Video: 173; Non-Video: 784; $\chi^2(1)= 212,44$; $p< .001$). On the assumption that a focused and detailed analysis results in less extensive but

Table 1: Distribution of relative frequencies (%) of student teachers` contributions by category and level

	Describing						Explaining						Critiquing					Proposing Alternatives					
Level	*1*	*2*	*3*	*4*	*5*	∑	*1*	*2*	*3*	*4*	*5*	∑	*1*	*2*	*3*	*4*	∑	*1*	*2*	*3*	*4*	∑	
Non-Video	0,5	2,25	3,75	2,25	0	**8,75**	1,5	3,25	2,75	0	0	**7,5**	39,5	22,75	2,75	0,5	**65,5**	7,5	9,25	1,5	0	**18,25**	**100**
Video	1,25	5,5	3,5	1,25	0	**11,5**	2	6,75	3,5	0	0	**12,25**	26,25	25,75	2	0	**54**	13,5	8,75	0	0	**22,25**	**100**

more meaningful contributions, this indicates that the video served both as external memory and reference point, which facilitated the process of grounding and thus shortened the contributions. Subjects of the test group (video) seemed to use more time for analyzing and reflecting on the lesson than for writing numerous and extensive contributions. Differences concerning the four categories were not significant, but it could be seen that using the video led to a more balanced lesson analysis and reduced student teachers` tendency to mainly critique the lessons. Results show that subjects of the test group tended to more often describe events of the lesson, explain certain teaching situations and propose alternative strategies, than to critique the recorded lesson (see Table 1). This might be due to the fact that the video allowed multiple perspectives on the lesson to be adopted and thereby promoted an analyzing rather than judging stance. Concerning the different levels of contributions, findings partly support the assumed benefits of video-based analyses: on average, descriptions in the test group reached lower levels, i.e. they were less elaborated. Video relieved students of the need to verbally describe a part of the lesson and thus led to shorter descriptions. The average level of explanations did not vary between test conditions. The most marked difference was found for critiques: subjects of the control group critiqued the lesson significantly more often without stating any argument ($t(27)= -2,59$; $p < .05$), whereas in the test group critiques more often contained an argument. Video thus seemed to promote students` deep analysis of the lesson and the process of reasoning. Unexpectedly the average level of alternatives was significantly higher for the control group (Video: AM=1,39; Non-Video: AM=1,68; $t(65)=2,02$; $p < .05$). One explanation might be that the details of the video impeded student teachers` process of generating alternative strategies. Though the students had very little experience in teaching and its analysis and despite the short testing period, nonetheless results show a number of desirable outcomes due to the availability of video. This encourages a further pursuit of this approach.

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Combining Structural, Process-oriented and Textual Elements to Generate Awareness Indicators for Graphical E-discussions

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Moderation of e-discussions can be facilitated by online feedback promoting awareness and understanding of the ongoing discussion. Such feedback may be based on indicators, which combine structural and process-oriented elements (e.g., types of connectors, user actions) with textual elements (discussion content). In the ARGUNAUT project (IST-2005027728, partially funded by the EC, started 12/2005) we explore two main directions for generating such indicators, in the context of a synchronous tool for graphical e-discussion. One direction is the training of machine-learning classifiers to classify discussion units (shapes and paired-shapes) into pre-defined theoretical categories, using structural and process-oriented attributes. The classifiers are trained with examples categorized by humans, based on content and some contextual cues. A second direction is the use of a pattern matching tool in conjunction with e-discussion XML log files to generate "rules" that find "patterns" combining user actions (e.g., create shape, delete link) and structural elements with content keywords.

Introduction

The term *awareness* is defined as "an understanding of the activities of the others which provides context for your own activity" (Dourish & Belloti, 1992). A great variety of tools for e-discussion and e-collaboration are available today, many of which offer awareness features for participants or moderators of discussions (for a review, see Soller, Martinez, Jermann, & Muehlenbrock, 2005). Awareness feedback in the different awareness tools has been based on various properties of the discussion, such as social interaction patterns, participation information, temporal stages and text analysis. An interesting example of feedback on structural issues in e-discussions is the DREW system (Baker, Quignard, Lund & Sejourne, 2003), which highlights opposing opinions in discussion graphs Yet, a systematic integration and combination of structural, process-oriented, and textual aspects has only recently been discussed in initiatives such as the Interaction Analysis project in the European Kaleidoscope network (http://www.noe-kaleidoscope.org).

One of the goals of the ARGUNAUT project (IST-2005027728, http://www.argunaut.org) is to obtain more meaningful indicators upon which to base online feedback to the moderators of synchronous graphical e-discussions. The methods described here were applied to the discussion products of a graphical e-discussion tool called Digalo (http://dunes.gr), but are relevant to other synchronous discussion tools, particularly graphical e-discussion tools.

Digalo discussions are held within an object space called a "map". Within this space, users contribute to the discussion by adding shapes representing argumentative ontology (e.g., rectangle for claims) and typing their text into them. Users may also link shapes to other shapes, using arrows of different types (support, opposition. reference). The shape and arrow objects may be modified or deleted. All user actions are logged, and XML log files are generated detailing all the actions taken by the users (e.g., user_1 created a claim shape at time_x). For each such discussion map, we can investigate structural, process-oriented and textual elements. The *structural elements* are the direct or computable attributes of each shape or arrow object (such as type, creator, number of characters) and any combination using these attributes as building blocks. The *process-oriented elements* are comprised of user actions on the discussion objects, and sequences thereof (stressing the dimension of time and the *process* of discussion rather than the end product). The *textual elements* are the free text contributions typed within each shape.

Within the context of the ARGUNAUT project, we are confronted with the challenge of combining some of the above-mentioned elements to generate awareness indicators. These awareness indicators will help us discover meaningful patterns in e-discussions. This approach is facilitated by the collaboration of specialized teams with expertise in various fields (pedagogy, argumentation, linguistics, software development, and machine learning). We believe our ongoing progress in this endeavor will have theoretical, pedagogical and technological implications for the evaluation of graphical e-discussions and for supporting the moderation of collaborative work and discussions.

Analyzing Graphical E-discussions: Methods and Initial Results

We have focused on two approaches to the analysis of e-discussions, combining structural, procedural and textual elements: machine-learning classifications and a rule-based approach for the definition and discovery of action patterns. These approaches are expected to yield complementary analysis results for e-discussions. We have applied these two approaches to Digalo log files of classroom e-discussions with some promising initial results. The following sections present both approaches and a brief summary of our progress so far.

During the conference, we plan on demonstrating both methods described below: the application of machine learning to our pre-annotated examples and the definition of action sequence patterns and pattern-matching log-file search for these patterns, using a specialized tool (also described below).

Machine-learning classifications

Taking a cue from previous work on automated analysis of collaborative argumentation (e.g., Domnez, Rosé, Stegmann, Weinberger, & Fischer, 2005), we applied machine-learning algorithms to the task of classifying the content of e-discussion contributions.

Graphical e-discussions (and specifically Digalo maps), may be coded or annotated at different levels of granularity. We began by focusing on *individual contributions (shapes)* as the classified units. We also classified contributions at a more complex unit of analysis, *paired shapes*, comprised of two contributions (shapes) and the link between them (arrow). This unit goes beyond a single utterance: it includes two distinct but related pieces of texts, and can only be interpreted or categorized using both contributions. Additionally, its definition includes structural relationships (a connector), and the interpretation of the intent behind the text must also consider the order of their appearance, a process-oriented element.

The attributes selected for single-shape classification included: the type of shape, the length of text within it, and the presence or absence of several classes of links (e.g., presence of outgoing links to a shape by the same user). We selected three sets of attributes at the paired-shape level for analysis: a basic set that did not consider the order of shapes (e.g., whether the shapes were created by the same user, their combined text length, type of connector), a set that assumed the shapes appeared in a particular order (e.g., whether the link created by the same user as the first shape), and a set that relied on our previous annotations for the shape level.

For each level of analysis, we created coding schemes based on theoretical, pedagogical and empirical considerations related to fostering productive collective argumentation. The coding schemes included, for example, labels such as 'task management' (shape level), and 'contribution followed by counter-argument' (paired-shapes level). The coding schemes are content-oriented, but take into account other elements (e.g., type of link), in some cases where the text's intention is unclear. The initial coding schemes were fine-tuned via a process of 2 or 3 coders annotating a small number of maps and subsequent discussion between them. The resulting schemes were used to code 42 Digalo discussion maps at the shape level, and 21 of those maps at the paired shapes level. Inter-rater reliability was assessed and coding differences were resolved by discussion or decision rules.

The coded sheets were then analyzed by a variety of machine-learning schemes, implemented within the WEKA framework (Witten and Frank, 2005, e.g., C4.5 Decision Tree, OneR, AdaBoost with OneR, PART), to try and generate accurate classifiers for new contributions. The initial results have been promising, in particular for the shape-level label of ‘critical reasoning’ (the C4.5 Decision Tree had 86% of overall accuracy) and the paired-shapes label of ‘question followed by answer’ (the PART algorithm had 94% overall accuracy). Some of the other classifiers also resulted in high accuracy, but relied too much on biased data (e.g., 89% of the shapes were 'on topic').

The Pattern Discovery Tool: Creating Rules to Detect Meaningful Action Sequences

The Pattern Discovery Tool, developed by the COLLIDE research group (Harrer, Vetter, Thür, & Brauckmann, 2005), was applied to the task of searching for patterns of user actions in e-discussion logs.

Sequences of actions, units comprised of sequential user actions logged by the discussion tool, can be considered process-oriented elements. Each action can be defined using the type of action (e.g., create, delete), the type of object(s) involved, the user(s) involved, and keywords to search for in the text parts of the objects. The generated PROLOG rule defining a sequence of such actions also includes a temporal element of order (first action, second action, etc.), and referencing information (for users and objects). For example, you can define a sequence in which a 'claim' shape is created by a user, modified by the same user, and later deleted by another user.

Our approach in the ARGUNAUT project is to pre-define possible action sequences which we think may be meaningful, i.e. representing specific theoretical or pedagogical phenomena, and to look for such sequences in XML logs of discussions. For example, consider a sequence in which one user creates a shape, another user creates a question shape (or a shape containing a question keyword) and then links it to the first user's shape, followed by the first user creating a shape with keywords such as 'because', 'reason', 'therefore' and linking it to the question shape. This could represent a request for clarification or reason (perhaps the initial contribution was an unsupported claim), which prompted the first user to give reasons for his or her opinion. This is exactly the type of pedagogical phenomenon within e-discussions that interests us.

However, the 'hits' for a particular rule in the discussion logs may not always reflect the phenomenon we wish to capture. We may therefore attempt to annotate the hits received according to whether they truly represent the semantic interpretation assigned to them ('good hits'), and then to use machine learning on these annotations (pending a sufficient number of coded examples to serve as a training set for classification learning).

Future Directions in the Support of e-discussion Moderation

Our vision is to utilize the products of the approaches described above to support the ARGUNAUT system, a tool currently in development. This tool is aimed at supporting online moderation of graphical e-discussions (e.g., Digalo discussions), providing meaningful feedback and advice to the moderators. The first prototype of the system, to be completed in January 2007, is expected to integrate an AI classifier for 'critical reasoning' as well as a few PROLOG rules that can identify action patterns.

It will take further theoretical and empirical work to reach a close-to-optimal set of indicators. To reach this goal, we plan to use an iterative process of experimentation and refinement, in which we will receive feedback from end users (moderators) about the effectiveness of the produced indicators. We also plan to observe and analyze the effect of the use of our awareness tools on the quality of e-moderation and e-discussion. However, we can already say that these innovative approaches to combining structural, process-oriented and textual elements have displayed great potential for analyzing graphical e-discussions and providing support to moderators of such discussions.

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The Relationship Between Student Interaction and Message Readability in Asynchronous Online Discussions

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Abstract: The current study explores the relationship between the readability of computer conferencing messages and the level of student interaction in asynchronous online discussions. Large-scale quantitative analyses were performed on the activity logs of 37 graduate-level distance education courses at the University of Toronto. The mean Reading Ease and Grade Level scores of student messages were found to be significantly correlated with the mean number of messages that students write, the percentage of student messages that reply to other messages, and mean message size. A correlation was also found between the readability of instructor messages and student messages. Consequently, the data suggest that a positive relationship exists between readability and the level of student online interactivity. Possible explanations for these results are discussed.

Introduction and Objectives

The current study examines the readability of messages in computer-mediated conferencing (CMC) courses, and the role that readability plays in online discussions. What relationship, if any, exists between the readability of conferencing messages and online activity patterns? Does writing style affect the volume of messages that students contribute to their online course? Is there greater interaction in courses that have more readable messages? How does the readability of student messages relate to the readability of teacher messages? By exploring these questions it is hoped that we can develop a deeper understanding of some of the factors that promote and sustain collaborative online discourse.

Background

Readability formulas predict the difficulty level of a text using mathematical equations. Two widely used systems for scoring readability are the Flesch Reading Ease score and Flesch-Kincaid Reading Level (Friedman & Hoffman-Goetz, 2006). The Flesch Reading Ease score rates text on a 100-point scale, with lower scores being more difficult to read than higher scores. The Flesch-Kincaid Grade Level formula is similar to the Flesch Reading Ease score, but it is converted to a U.S. grade level equivalent (Friedman & Hoffman-Goetz, 2006). Both algorithms are based on the word and sentence length of a text. Although other types of tests are available, these two are extensively used, in part because they are features of Microsoft Word and are thus easily obtained.

Despite their widespread popularity, readability formulas have been the subject of much academic scrutiny. Klare (1963) identified a number of limitations associated with readability measures. Since readability assessment involves the quantification of textual features, important elements such as word order, content, and organization are left unaccounted for. Redish (2000) suggests this problem is exacerbated by the fact that formulas consider only one or two textual features, usually word and sentence length. Readability may also be dependant on readers' topic preferences, resulting in scores that are highly variable (Dufty, Graesser, Louwerse, & McNamara, 2006), or scores that differ between parts of the same text (Redish, 2000). In spite of these criticisms, many researchers view readability formulas as valuable tools. Of particular appeal is their simplicity and ease of use. Readability measures also serve purposes other than assigning appropriate grade-levels. For example, readability formulas have become standard features on many word processing programs, making it possible for authors to measure the difficulty of a text while still in the process of writing it.

Readability is arguably associated with online CMC culture. Many researchers have explored the importance of community on student interaction in online discussions (Wegerif, 1998; Garrison, Anderson, & Archer, 2001). Romanoff (2003) observes that although online discourse increases the physical distance between conferencing members, "…it can also serve to reduce that distance by enhancing the sense of community among students and teachers" (p. 58). In addition to learning from each other (Brown, 2001) students establish relationships with other members of the class, resulting in feelings of acceptance and well-being (Wellman & Guila, 1999). According to Collison, Elbaum, Haavind, and Tinker (2000), regular participation and a demonstrated concern for others are hallmarks of a healthy online community. Regular participation is a reflection of open communication, and indicates intellectual trust between participants (Collison, et al., 2000). Message readability would be expected to influence the openness of communication and mutual trust within such a community. However, message readability, which is presumably an important influence on online collaboration and communal development, has not been examined in the research literature. The current study begins to address this issue by examining the relationship between readability and interaction using a large dataset of 37 computer conferencing courses.

Method and Data Sources

Data were collected from 37 graduate-level distance education courses offered at the University of Toronto between January 2003 and December 2005. To be considered for the study, a course had to satisfy several conditions. First, the course had to be delivered purely online, without any face-to-face components. Second, the course had to utilize the course web-based conferencing system Knowledge Forum, which maintains time-stamped logs of student's online activity. Lastly, the central activity of the course had to be participation in the asynchronous discussion forum. Adherence to the preceding conditions ensured that the courses were comparable in design and pedagogy, making it easier to study message readability across courses.

The class sizes in the dataset ranged from 5 to 21 students and all courses were 13 weeks in length. They took the form of a series of weekly seminars in which learners were expected to discuss assigned class readings in a shared asynchronous threaded environment. Fourteen different instructors taught the 37 courses. Web Knowledge Forum records detailed time-stamped logs of each time that an online participant opens or saves a message. The full text of all messages is also preserved. The current study used this data to explore the relationship between the following measures in each course:

1. Readability Measures: Two common measures of readability were adopted for the study: Flesch Reading Ease score (ranges from 0 to 100) and the Flesch-Kincaid Grade Level.
2. Message Count: The message count is the total number of messages contributed to an online course by a student.
3. Interactivity Ratio: The student interactivity ratio is the percentage of messages that a student contributes as "replies" to one of their classmate's contributions. The Interactivity Ratio is calculated for each participant by dividing the number of "replies" by the total number of messages written. A high ratio (a value close to 1.0) suggests a high degree of interactivity.
4. Message Size: The message size is the average size of all messages written by a student, in words.

Course averages were computed for each of the preceding measures by averaging the scores of individual students. Thus, for each of the thirty-seven courses, the following student and teachers mean scores were calculated: Reading Ease, Grade Level, Message Count, Interactivity Ratio, and Message Size.

Results

An analysis of the data revealed a number of statistically significant correlations involving the readability of conferencing messages. Since the correlations used data from 37 courses, there were 35 (N – 2) degrees of freedom for all statistical tests. The findings are as follows:

Readability and Messages Written

The number of messages written by students was strongly correlated with their Reading Ease scores (r = .62, p < .01), and negatively correlated with their Grade Level scores (r = -.55, p < .01). Accordingly, the results suggest that a relationship exists between the readability of student messages and the number of messages they write. Productivity, at least in terms of message generation, appears to be associated with more readable text.

Readability and Interactivity

The student interactivity ratio correlated positively with both the Reading Ease scores of students' messages (r = .25) and teachers' messages (r = .38, p < .05), although only the latter was statistically significant. Student interactivity was also negatively correlated at a statistically significant level with both student (r = -.42, p < .05) and teacher (r = -.43, p < .01) Grade Level scores. All of these correlations offer evidence of a relationship between readability and interactivity. (Note that low Grade Level scores are an indicator of highly readable text). These findings suggest that levels of interaction are tightly tied to the readability of student and teacher messages.

Higher proportions of learner interaction are associated with a class-wide tendency to produce more readable messages.

Readability and Message Size

The mean message size of student conferencing messages correlates positively with their Grade Level scores ($r = .75$, $p < .01$), and negatively with their Reading Ease scores ($r = -.62$, $p < .01$). Both correlations were strongly significant, suggesting that courses containing longer students messages also contain less readable messages, on average. In contrast, the mean message size of instructor messages was not significantly correlated with readability measures. Thus, while students often use more complex language when writing longer messages, teachers do not share this tendency. The combined results of this analysis and the first analysis (i.e., "Readability and Messages Written") suggest that courses that contain highly readable messages tend to contain a significantly greater number of messages, but messages that are shorter in length.

The Relationship Between the Readability of Teacher and Student Messages

Student and teacher Reading Ease scores were significantly correlated ($r = 0.35$, $p < .01$). The correlation between teacher and student Grade Level scores was also positive ($r = 0.24$), but it was not statistically significant. These results offer some evidence that a relationship exists between the students' style of writing and that of their instructor. That is, if a teacher produces highly readable text, then the students in the class are also likely to produce readable text. Whether this relationship is causal (e.g., the teacher serves as a model of writing practices for students) or due to other factors (e.g., complexity of content) is unclear.

Conclusions

The preceding analyses uncovered a number of relationships between readability and online interaction. Statistically significant relationships were discovered between the readability of student messages and (i) The number of messages students write (positive correlation); (ii) The size of student messages (negative correlation); and (iii) The percentage of messages that reply to other messages (positive correlation). In other words, in courses in which student messages score higher on the two readability metrics, there is greater interaction and more message-writing (although the messages are significantly shorter in length).

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The Relation between Schoolteachers' Perceptions about Collaborative Learning and Their Employment of Online Instruction

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Abstract. The gap between known benefits of socio-constructivist pedagogies to online instruction, and schoolteacher practices has been widely documented. To better understand the gap this research characterizes the range of schoolteachers' online practices and the relation between their pedagogical perceptions and these practices. Two groups of teachers were studied: Novices and leaders in online instruction. Data-sources included interviews, researcher's journal and online activities developed by teachers. Findings indicate that leading teachers develop activities that better utilize the technology, require higher levels of thinking, better connect contents to student lives, and scaffold for rich artifacts. However, both groups scarcely utilize collaborative learning in their activities. We claim that this teacher-centered approach plays a critical role in preventing "ordinary" teachers from regular employment of online instruction. Only teachers who considered themselves "online freaks" were able to withstand the demands of this approach to online instruction.

Introduction

Good implementation of online instruction can support meaningful learning and assist teachers in coping with didactic, content-related and organizational issues (Salomon, 2000; Dori, Tal & Peled; 2002, Linn, Davis & Bell, 2004). Such implementation can increase students' interactivity and improve their thinking and social skills (Rochelle et al., 2000; Koszalka, 2001; Kali & Linn, in press; Linn et al., 2004). In light of the awareness of the affordances that technology offers instruction, Salomon (2000) presents a vision whereby technology will serve pedagogy (rather than vice versa, which he claims is the common case), and will assist in its realization: The technology will enable access to information and provide the interactive and collaborative tools, while the teacher will create learning situations that utilize these tools. Such situations will require learners to develop higher-order thinking skills and promote their competence to work collaboratively. Recent research supports this vision, by illustrating how socio-constructivist pedagogies translate into design principles that can guide planning and developing of online instruction, which utilize the added value of technology (Kali, 2006, Kali & Linn, in press). However, the realization of this vision is still far from reality. Most online instruction requires information gathering and low level processing (Rochelle et al., 2000; Fishman et al., 2001; Mioduser & Nachmias, 2002; Herrington, Reeves & Oliver, 2005). This is especially true for k-12 settings. Research shows that online instruction is gradually integrated into schools, but that most educational websites designed by teachers represent conservative pedagogical perceptions (e.g., Lehtinen et al.,1998).

Fishman et al. (2001) claim that teachers' implementation of technology is greatly influenced by their personalities, professional knowledge, experience and pedagogical perceptions. The more a teacher experiences success using educational technology, the more positive will be her perception regarding technology's capacity to advance teaching and learning, and the more she will perceive it as an opportunity for personal professional development (Rogers, 1995; Kumari, 1996; Koszalka, 2001). Activities designed by teachers reflect their perceptions, educational goals, professional knowledge and the constraints they face. Additionally, personality traits affect the method and the extent to which online instruction is used. Fuller et al. (2000) claim that teachers who assimilate and develop online learning environments are characterized by flexibility and willingness to take risks.

This research characterizes the range of the online practice of teachers in the formal Israeli education system and examines the relation between their pedagogical perceptions and these practices. The range of online practice was defined by means of its two extremities: At one extreme, teachers who are making their first steps in implementing online instruction, and at the other extreme, teachers who are considered to be online leaders. The characterization focused on examining the extent to which socio-constructivist learning approaches are implemented in online activities developed by the teachers.

Methods

Sample

Novice Teachers

The group of novice teachers included 25 teachers from two schools (one elementary and one junior high) who were on their first year of a teacher professional development (TPD) program for online instruction. The TPD program, instructed by the authors of this paper, focused on construction of an interactive website for class activities, using an online learning content management system (LCMS). We chose to work with teachers who were motivated and who were willing to learn and to assimilate online instruction. Teachers in this group varied in their age and teaching experience. Teacher guidance was performed: a) individually or in pairs in one-hour weekly meetings throughout one year, and b) in several longer staff meetings. The school principals also participated in some of the staff meetings.

Leading Teachers

The group of leading teachers included four high school and junior high school teachers, who were defined, on a national level, as "online leaders". Three of these teachers received national awards for their online practices. These teachers, who had participated in the past in various TPD programs for online instruction, define themselves as "online freaks". In their current practice they develop and maintain websites for their students in a variety of science topics, and participate as instructors in TPD programs.

Tools and Data Sources

Interviews (Leading Teachers)

Two semi-structured two-hour interviews were conducted with each of the four teachers. The first interview documented the process each of the teachers went through until attaining the status of "leading teacher". In this interview, we also wanted to understand the teachers' positions regarding the added value of integrating online instruction. In the second interview, the teachers presented selected activities from their websites, explained the pedagogical thinking that guided them in the development of the activities, and explained how the activities contributed to the teaching and learning in their classes.

Researcher's Journal (Novice Teachers)

The relationship with the group of novice teachers was ongoing and lasted throughout the entire year. We therefore used a researcher's journal as the primary tool for collecting information from this group of teachers. The journal documented the meetings and insights that emerged during the meetings and conversations held with these teachers.

Activities Developed by Teachers

The activities developed by both novice and leading teachers were a main information source to characterize the range of online practice. Teachers from each of the groups constructed class-sites which included all the online activities they developed. The four leading teachers had rich websites with dozens of activities each, while novice teachers had class-sites with fewer activities. For the purpose of the research, we decided to randomly select from these websites a total of 20 activities per group (a total of 40 activities). The activities represent a broad range of contents, covering both humanities and scientific topics and designed for a wide range of ages, from elementary level to high school level.

Rubric for Characterizing and Analyzing of Online Activities

Several theoretical frameworks exist that describe the characteristics of online instruction (see for instance, Mioduser & Nachmias, 2002; Tubin et al., 2003; Herrington, Reeves & Oliver, 2005). However, since we wanted to evaluate, both quantitatively and comparatively, online activities developed by teachers from both groups, we had to develop a rubric that would enable us to do so (Table 1). The rubric we developed comprises six dimensions that constitute a measure of "good" teaching according to a socio-constructivist perspective. For each dimension, three performance levels were defined: low, intermediate and high.

Data analysis focused, first, on using the rubric to characterize the online activities designed by the teachers, and second, on analyzing the interviews and researcher's journal in order to characterize the pedagogical perceptions held by novice and leading teachers regarding the integration of online instruction in their practice. This analysis enabled us to find a relationship between the perceptions of the teachers from both groups and the pedagogical design of the activities they developed.

Table 1: Rubric for Characterizing and Analyzing Online Activities

Dimension	High Level (3)	Intermediate Level (2)	Low Level (1)
Use of the Technology's Added Value	Technology is essential for the activity. Students are referred to a variety of rich, current websites that can assist in understanding the contents.	The technological component might create interest and innovation, but with no fundamental change in the essence of the learning.	Use of technology is technical and does not affect the essence of learning. Students download traditional worksheets, fill them out and return them to the forum or directly to the teacher.
Required Level of Thinking	The activity encourages higher order thinking: (posing questions, taking a stand, making conclusions) and encourages creativity, responsibility and knowledge integration. (Levels 3-6 - Bloom, 1956)	The activity requires the learner to give examples, descriptions, summaries or general explanations of information gathered from the internet. (Level 2 - Bloom, 1956)	Memorization of knowledge. Focus on standard questions and answers. Oriented towards simple information-gathering assignments. (Level 1 - Bloom, 1956)
Peer Learning	Online components used to support collaborative learning as an essential part of the activity. Learners serve as information sources for their peers.	Scaffolds explicitly require students to work in pairs or groups, but there is no technological support for interaction between fellow students or between the groups.	There is no reference to collaborative learning. Learners are sometimes prevented from cooperating with one another. Projects are occasionally uploaded to the forum, but only for review by the teacher.
Making Contents Accessible	The activity is connected to the learner's cultural world and previous knowledge and experience, by choice of contents, nature of problems; social context.	An attempt is made to relate the activity to the learner's world, but the connection is artificial or not meaningful.	There is no attempt to relate and make the contents accessible. Emphasis is on content that the learner must know or remember.
Scaffolding for Rich Artifacts	Structured and scaffolded assignments, that help learners construct an artifact, and enable the teacher to serve as a facilitator. Artifact is diverse, creative and promotes personal capabilities and self-expression.	Scaffolds enable a product with a certain degree of openness and personal expression, but are too general to support a complex task. For instance, "Write a story about…", "What I would do if…", "My opinion on…"	Scaffolds guide towards a uniform, closed artifact defined by the teacher. No creativity is required to produce the artifact. Such activities include: standard questions and answers, sorting of data in a table, etc.
Embedded Assessment	Assessment is performed by the teacher or by fellow students according to clear and known criteria. Formative assessment is embedded in the learning process and enhances it.	There is reference to the assessment of artifacts, but no clear criteria are presented. Artifacts are sometimes presented on the website or in class, but without prompts for further learning from these artifacts.	There is no reference to the way in which the learner is assessed. Assessment is summative. Products are sent to the teacher to be checked and graded.

Findings

Online Activities Developed by Teachers from the Two Groups

Figure 1 shows the frequency distribution of the levels of the activities developed by the two groups of teachers and illustrates the difference between the two groups. The distribution of the activities developed by the novice teachers tend more toward the lower levels: 8 activities at the 1-1.5 level (40%); 9 activities at the 1.6-2 level (45%); 3 activities at the 2-2.5 level (15%) and no activities at the 2.6-3 level. The distribution of activities developed by the leading teachers is more symmetric: 3 activities at the 1-1.5 level (15%); 7 activities at the 1.6-2 level (35%); 6 activities at the 2-2.5 level (30%); and 4 activities at the 2.6-3 level (20%). T-test reveals that the difference between the mean value obtained for all the novice teachers' activities (1.6) and that obtained for all the leading teachers' activities (2.1) is statistically significant (P<0.001).

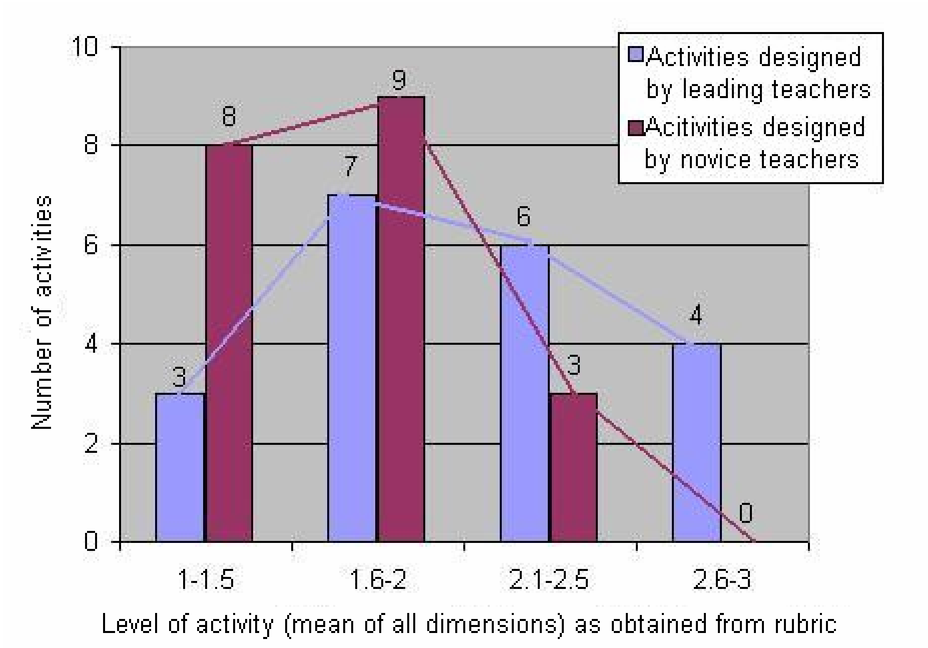

Figure 1 - Distribution of Activities Developed by the Two Groups of Teachers, by Level (N=40)

In order to better understand the differences between the activities developed by teachers from the two groups, we present the values obtained using the rubric for each of the pedagogical dimensions investigated (Figure 2).
(* designates significant difference, P<0.001)

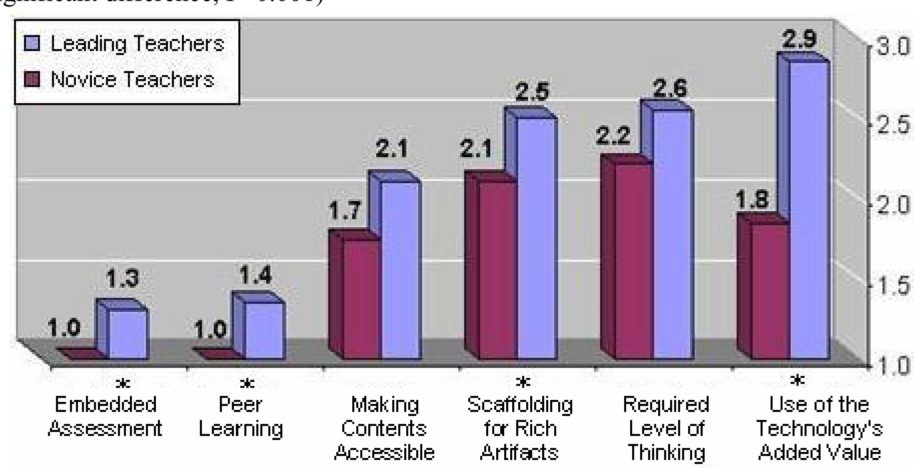

Figure 2: Online Activities Developed by leading teachers (N=20 activities) and Novice teachers (N=20 activities)

As seen in Figure 2, the leading teachers rate significantly higher on all of the dimensions examined. A statistically significant difference was found for all of the dimensions except for *Required level of thinking* and *Making contents accessible*. The greatest difference between the two groups of teachers was in the dimension that examined the *Use of the technology's added value* (1.8 for novice teachers vs. 2.9 for leading teachers). In other words, in activities developed by leading teachers, technology is an essential support; it enriches the contents with visualizations and with a variety of links that are both updated and relevant to the learning; it supports active learning and encourages online dialogue. On the other hand, the novice teachers tended to guide the learner in a more conservative teacher-centered approach; they typically constructed worksheets with traditional teaching characterizations and uploaded them to the site so that students would be able to complete and submit with answers.

The dimension *Required level of thinking* shows that teachers from both groups are aware of the need to encourage learners to function at high levels of thinking. Values obtained for this dimension, were relatively high (2.2 for novices vs. 2.6 for leaders) and the difference between the two groups was not statistically significant. Nevertheless, the activities constructed by the leading teachers were found to better guide learners towards the use of high-order thinking skills, in which learners were required to perform assignments that involved drawing conclusions, posing questions and synthesizing information.

Analysis of the dimension *Scaffolding for rich artifacts* revealed that activities developed by the leading teachers included structured and detailed scaffolds that encourage autonomous learning and guide learners to create rich, varied and creative artifacts (2.5). Despite the statistically significant difference between the two groups, the activities of the novice teachers also achieved relatively high values on this dimension (2.1) compared with other dimensions. The relatively high values obtained stem from an emphasis in these activities on the need to encourage the learner's creativity (for example, "Write an essay about…"). Nevertheless, these activities, unlike activities developed by the leading teachers, did not provide sufficient scaffolding to assist students in constructing the artifacts.

Analysis of the dimension *Making contents accessible* revealed that the two groups of teachers do not sufficiently use knowledge from the students' daily lives to make the teaching contents more accessible. Although the values obtained for the activities developed by the leading teachers were slightly higher than those obtained for the novice teachers (2.1 vs. 1.7, respectively), it seems that the emphasis in the activities of both groups was placed primarily on the hierarchical structure of the contents and not enough on finding ways to make these contents accessible.

The two dimensions that rated lowest for both groups were *Embedded assessment* and *Collaborative learning* (1 vs. 1.3 and 1 vs. 1.4 for novice vs. leading teachers, respectively). In other words, both leading and novice teachers do not regard the computer as a tool that can assist in providing alternative assessment and both groups of teachers fail to sufficiently encourage online collaborative learning. Although for both of the teacher groups these two dimensions rated low compared with the other dimensions, there was still a statistically significant difference between the two groups. For instance, analysis of the dimension *Embedded assessment* showed that leading teachers frequently present the criteria for assessment of the required artifacts within the activity. However, technology is not used to perform any ongoing embedded assessment, but rather only to send the artifact to the teacher and to receive summative assessment. Artifacts are occasionally displayed on-site, but they are assessed by the teacher only. Only two of the twenty activities developed by leading teachers contained any reference to peer assessment. Among novice teachers, on the other hand, no reference at all was made to this dimension in all of the twenty activities examined.

A statistically significant difference which we pay special attention to, was found between the two groups with respect to the second low-rating dimension, *Collaborative learning*. Among the novice teachers, no reference at all was made to this dimension, whereas among the leading teachers, we found only slight implementation of collaborative components in their online teaching. Only five out of the twenty activities developed by the leading teachers contained any reference at all to this dimension. In these activities, students were required to express their opinion about artifacts created by their fellow classmates. Alternately, scaffolds were such that they guided the students towards working collaboratively in class on the construction of artifacts. No scaffolds were found for the use of technology as a tool that promotes collaborative organization of knowledge or interaction between student groups.

In order to enable the reader to gain some idea about the characteristics of the activities and the way in which we analyzed each one of them using the rubric, we now present sample analyses of two activities developed by the teachers. The first, which we rated high, was developed by a leading teacher, and the second, rated low, was developed by a novice teacher.

Example of an Activity Rated High Using the Rubric

Genes for Breakfast is an activity designated for 9th grade science students. The activity starts by presenting for discussion, the problem of genetically engineered food as it exists today in various countries, and its possible affect on our health. Students are asked to write their personal opinion on the subject and to refer to the opinions of others in a forum. Later on, the activity guides the students to work in teams to explore the subject from different aspects using links provided in the site. Finally, the students are required to present in class the advantages and disadvantages of consuming genetically engineered food, according to the approach they choose to represent. This activity constitutes an example of the meaningful use of technology, which integrates exposure to varied information and active discussions on the forum (Use of the technology's added value = 3). The issue is presented from a perspective that is accessible to the students and it refers to their personal opinions (Making contents accessible = 3). The activity encourages synthesis and presentation skills (Required level of thinking = 3) and active scientific inquiry as well as the creation of varied artifacts (Scaffolding for rich artifacts = 3). Students are required to work collaboratively in groups, to present the artifacts to the entire class and to address the opinions of their peers in an online discussion (Collaborative learning = 3). However, there was no reference in this activity to the assessment dimension (Embedded assessment = 1).

Example of an Activity Rated Low Using the Rubric

Idioms is an activity intended for 5th graders and includes a crossword puzzle and a list of words to be used in its solution. Students are required to download the file and fit the words from the list into the crossword puzzle according to definitions that appear in the file. If they fit the words in correctly, they should obtain a sequence in the middle of the crossword puzzle that contains an idiom that was previously learned in class. The activity offers a link to an online idiom glossary (a website containing idioms and their meanings). The idiom glossary can help the learners if needed, but there is no explicit instruction as to the way it can be used. This activity is an example of an assignment in which the use of technology is technical and has no effect on the essence of the learning. The students download the file, follow the instructions and submit their work to the teacher (Use of the technology's added value = 1). The link to the online idiom glossary does not change the activity's essence, since it is unrelated to the instructions the students receive and does not serve as a tool to raise the learner's level of thinking (Required level of thinking = 1). The artifact is uniform and defined by the teacher (Scaffolding for rich artifacts = 1) and there is no attempt to relate the contents to the learner's world; The activity deals with an idiom that was learned in class and it makes no current or relevant use of it, which might stir up some interest among the learners and require them to use their personal knowledge (Making contents accessible = 1). Again, there is no reference to the collaboration dimension (Collaborative learning = 1) or to the assessment dimension (Embedded assessment = 1).

Pedagogical Perceptions of Novice and Leading Teachers

The analysis of the researcher's journal and the interviews held with the two groups of teachers helped us identify their perceptions regarding the role of online instruction in their practice and the way in which they perceive the added value of its use. Table 2 presents the main perceptions of the two groups of teachers as they emerged from the typical statements collected from the researcher's journal and from the interviews (white cells in the table represent similar perceptions, and gray cells represent different perceptions between teachers in the two groups).

The table reveals that teachers from both groups had similar perceptions regarding three aspects of online instruction (Online instruction assists in personal and professional development; Role of online instruction in teaching practice; and Value of peer learning). Their perceptions with respect to two other aspects (Role of online instruction in daily life and Online instruction as a means for creating dialogue) were, however, different.

Table 2: Perceptions of teachers regarding the integration of online instruction in teaching

Perception Categories	Novice Teachers	Leading Teachers
1) Online instruction assists in personal and professional development	- Enhances the personal professional development process - Empowers the teacher's place within the school community and outside of it - Enables the teacher to autonomously construct professional activities	
2) Role of online instruction in teaching practice	- Diversifies, improves and enriches teaching and learning - Enhances student motivation - Exposes students to current information that is attractive and relevant to their learning	
3) Value of peer learning	- Teachers do not support peer learning. They range from total objection (novices) to acceptance due to system constraints (leaders), but not due to an understanding of the pedagogical benefits of collaborative learning.	
4) Role of online instruction in daily life	- Imposes an additional burden on the teacher - Perceived as a random and non-permanent project activity	-Is an aid to teacher, an integral part of daily teaching
5) Online instruction as a means for creating dialogue	Online instruction is not considered as a means for dialogue with students. Dialogue is limited to classroom boundaries of time and place.	Online instruction is considered as a means for creating an ongoing educational dialogue between teacher and student, also after school hours.

White represents perceptions that are similar; Grey represents perceptions that are different.

Discussion and Conclusions

The findings indicate that there are significant differences in the characteristics of online practices of teachers from the two groups, despite the fact that they are similar in most of their pedagogical perceptions regarding online instruction. With regards to practices – the leading teachers were, in most cases, rated on the high range of the scale. The activities they developed were higher in all dimensions examined. The novice teachers, on the other hand, use technology to implement conservative pedagogical approaches and, as a result, the activities they developed rated lower in all of the dimensions examined. These teachers tended to construct traditional activities, which focus on information gathering and rote learning. The digital communication with students in this group was mainly for purposes of administration and organization rather than for pedagogical objectives.

With regards to perceptions – the findings indicate that teachers from both groups exhibited positive perceptions regarding the need to integrate online instruction. For them, this is an important means for improving and diversifying teaching, which enables to expand the world of information available to the students and increase their motivation. Teachers from both groups also feel that the school website reflects the activities and events in the school and believe that their meaningful use of online instruction will grant them professional appreciation by the school management, the parents and the students. For them, this is an opportunity to gain professional development and to accept professional recognition within the school and outside of it.

We believe that the differences between the two groups' online instruction practices, as depicted from the activities they developed, are related to two aspects in which the two groups differed in their perceptions. The first difference is in the teachers' perception of the role of online instruction in their daily life. The leading teachers made online instruction an inseparable part of their practice. They use online instruction to expand learning beyond the school boundaries of time and place, which, according to the leading teachers, improves their work, enriches the learning and even enables them to get more work done. Perceiving online instruction as a tool that makes teaching more efficient is a significant factor in their desire to continue using it on an ongoing basis. As apposed to this view, the novice teachers regard online instruction as a burden that makes them work harder, while receiving no additional compensation. As far as they are concerned, online teaching constitutes a noncommittal activity, a refreshing addition to the regular learning, but one that is not an ongoing daily part of their practice.

The second difference was found in the high availability of the leading teachers for communication with their students. Leading teachers regarded online instruction as a means for creating an ongoing learning dialogue with the students and for providing individual assistance if necessary. The possibility of holding such a dialogue enables the teachers to support students and to form personal relationships with them, but also requires that the teachers commit to being available for the students and to assist them at all times. It is no wonder, therefore, that not all teachers are willing to make that commitment after school hours. Such a commitment serves, for many teachers, as a deterrent, and they prefer the face-to-face dialogue limited to the time and space boundaries of the classroom.

It is reasonable to assume that most of the differences in the activities developed by the two groups can be explained by the vast experience that the leader teachers acquired. Their perseverance brought them to develop a culture, in which online instruction is inseparable from their teaching practices. It is clear that this kind of culture cannot develop among teachers who see online instruction as burden. The latter teachers, who will probably continue to use technology sporadically, if it all, will not have the opportunity to develop the expertise in designing online activities, which the leading teachers have developed. If that is the case, the question is raised as to how to support the development of sustainable online practices among novice teachers, which would enable them to gradually develop expertise in developing meaningful activities?

Part of the answer might be found in the low values obtained for the *Collaborative learning* dimension for activities developed by teachers from both groups. We regard this as one of the most important findings in the study. These low values reflect the pedagogical perceptions of both groups regarding peer learning, which were found as negative and even antagonistic for both groups. Although the leading teachers occasionally implement online discussion, they do not encourage peer learning of the kind that enables learners to share knowledge, consult with each other and construct common knowledge together. The novice teachers exhibited greater objection to the implementation of collaborative learning; They saw it as a complete waste of time. In fact, teachers from both groups did not consider peer learning to be a resource that can contribute to classroom teaching and learning. Collison et al. (2000) present an approach to online instruction in which the capability of technology to enable dialogue between students, might free the teacher from the need to be an exclusive source of guidance for each and every student. They call this the "Moving out of the middle" approach, or MOOM. In this study, teachers from both groups did not realize the support they can gain from peer learning of their students, and thus only those few that were “online freaks” were able carry out the tremendously demanding task of teacher-centered online instruction. We claim that the student-centered approach to online instruction, which takes advantage of collaborative learning strategies, is the key to adoption of online instruction also by “ordinary” teachers, who will be willing to integrate it into their practices if they will not need to become enslaved to it. We recommend that future TPD programs place emphasis on making online instruction more sustainable for “ordinary” teachers, by fostering a student-centered approach, and specifically, by realizing the added value of collaborative learning to support online instruction.

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Influence of group member familiarity on online collaborative learning

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Abstract: This study investigated the effects of group member familiarity during computer-supported collaborative learning. Familiarity may have an impact on online collaboration, because it may help group members to progress more quickly through the stages of group development, and may lead to higher group cohesion. It was therefore hypothesized that increased familiarity would lead to (a) more critical and exploratory group norms, (b) more positive perceptions of online communication and collaboration, (c) more efficient and positive collaboration, and (d) better group performance. To investigate these hypotheses, 105 secondary education students collaborated in groups of three. The results of this study indicate that familiarity led to more critical and exploratory group norm perceptions, and more positive perceptions of online communication and collaboration. Furthermore, in familiar groups students needed to devote less time regulating their task-related activities. On the other hand, no effect of familiarity on group performance was found.

Introduction

Over the past 20 years, research on computer-supported collaborative learning (CSCL) has helped support the claim that collaborative activity among students can effectively be supported with computer technology. The accumulated knowledge concerning effective CSCL has also led to detailed design guidelines for CSCL (e.g., Kirschner, Martens, & Strijbos, 2004). In spite of these design guidelines, researchers still experience problems when students collaborate using computer technology (e.g., conflicts, communication difficulties, shallow discussions). Although these problems may be caused by poor implementation of the design guidelines mentioned, it may also be the case that research has focused too little on potential moderators that can influence the effectiveness of CSCL (Hollingshead & McGrath, 1995) such as time spent on group work (e.g., one session versus prolonged group work), task type (e.g., open versus closed tasks), group size (e.g., small versus large groups), and group or student characteristics (e.g., estrangement versus familiarity of group members). For example, how well students know each other prior to their collaboration may have an impact on several aspects of their collaboration (Kiesler & Sproull, 1992). Ignoring such moderators may lead to inconsistent and contrasting results, making it very risky to draw generalizations.

The aim of this contribution is to examine the effect of one potential moderator, namely group member familiarity. Kiesler and Sproull (1992) identified group member *familiarity* as an important factor to consider when designing CSCL. The effects of familiarity on group interaction and performance are related to aspects of Tuckman's (1965) stages of group formation: forming, storming, norming, and performing. It has been hypothesized that when group members know each other well, they will spend less time forming a coherent group, and will establish group norms more easily, and thus, reach the performing stage more quickly. This is thought to have beneficial effects for, among others, *satisfaction* with online collaboration and *group performance* (Adams, Roch, & Ayman, 2005).

Although only a small number of studies has investigated the impact of group member familiarity on CSCL (e.g., Adams et al., 2005; Mennecke, Hoffer, & Valacich, 1995; Smolensky, Carmody, & Halcomb, 1990), researchers have identified possible positive and negative consequences of increased familiarity among group members. For example, Adams et al. (2005) found that when group members knew each other better, their satisfaction with the group process increased, though their decision accuracy decreased. Similarly, Smolensky et al. (1990) found that familiarity had a negative impact on students' interactive behavior, which, in turn led to decreased group performance. In contrast, Mukahi and Corbitt (2004) found no relationship between familiarity and students' collaborative activities.

An explanation for the mixed results may be the different operationalizations of familiarity (Adams et al., 2005). Adams et al., for example, following Gruenfeld, Mannix, Williams, and Neale (1996), asked students to rate familiarity with group members on a 4-point scale. Smolensky et al. (1990), on the other hand, did not measure familiarity directly but asked half of their participants to bring two friends to their experiment, so as to create familiar and unfamiliar groups, thus equating familiarity with friendship. In our opinion, students can be familiar with each other without being friends. In this study, familiarity was operationalized by asking students, before the start of their collaboration, to indicate how well they *knew* the other group members. This way, the collaboration itself does not affect students' judgments of familiarity. On the other hand, asking students to rate familiarity before the collaboration may draw attention to whether they worked with friends or strangers, which may also influence students' collaborative behavior.

Our study differed from previous studies on familiarity on several aspects. In contrast to other studies, students in our sample came from existing secondary education classes, thus most group members knew their teammates to a certain extent, although variations obviously existed. In other studies, students were recruited from a pool of student volunteers (Adams et al., 2005). Additionally, the study presented here was carried out in an authentic educational context, in which students collaborated online for a longer period of time. In contrast, in other studies the effects of familiarity were often examined in a single online session, while students worked on group tasks with little or no relationship to the curriculum (e.g., Mennecke et al., 1995; Orengo Castellá, Zornoza Abad, Prieto Alonso, & Peiró Silla, 2000). Furthermore, most studies that examined the role of familiarity during online collaboration focused on either students' perceptions (e.g., their satisfaction with the collaborative process) or on students' interactive behavior (e.g., use of negative speech). This study will focus on perceptions as well as behavior.

Thus, in order to extend the research findings concerning familiarity, this paper focuses on the effects of familiarity on (a) perceived group norms, (b) perceptions of online collaboration and communication, (c) students' collaborative activities, and (d) group performance. The remainder of this introduction focuses on describing the possible effect familiarity may have on these four variables.

Group norms

As groups include group members who are more familiar with one another, students may be more comfortable expressing *disagreement* (Gruenfeld et al., 1996). As such, familiarity may help group members to adopt critical or exploratory group norms instead of consensus norms (Postmes, Spears, & Cihangir, 2001). This is important because critical or exploratory group discussions have been shown to lead to more effective group work (Wegerif, Mercer, & Dawes, 1999). During critical group discussion, students do not hesitate to question each others' opinions, that is to disagree with one another (Postmes et al.). Exploratory group discussions are similar to critical group discussions in the sense that students accept criticism from each other and discuss alternatives. In addition, these kinds of discussions should be held in a *constructive* manner. In other words, conflicts and disagreements are welcome, but group members should try to resolve them. Furthermore, during exploratory discussions group members share relevant information and encourage each other to participate (Wegerif et al.). It is expected that familiar group members will be more likely to develop group norms which value critical or exploratory online discussions because they do not feel the social pressure to agree with other group members (Adams et al., 2005). Unfamiliar group members may be more prone to adapt to such pressure. These critical or exploratory versus consensual group norms will be developed in the norming stage of group formation (Tuckman, 1965). Thus, the following hypothesis may be formulated:

H1 Group member familiarity will contribute to more critical and exploratory group norms.

Perceptions of online communication and collaboration

In familiar groups, group cohesion will likely be higher because group members feel more *comfortable* with the other members (Adams et al., 2005; Mennecke et al., 1995). Furthermore, when group members know each other better, they may be able to communicate and collaborate efficiently (Adams et al.). This will lead familiar group members to perceive their online communication and collaboration within their group as being more positive. Students may also perceive their communication and collaboration more positively in familiar groups because *psychological safety* is higher in these groups (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006). Indeed, studies by Mennecke et al. and Adams et al. found more positive perceptions of communication and collaboration in familiar groups. Therefore, a second hypothesis will be investigated:

H2 Group member familiarity will lead to positive perceptions regarding the collaborative process.

Collaborative activities

As familiarity between group members increases, communication and coordination of collaboration may take less *effort*. For example, the transfer of information relevant to executing the task may be more efficient, and misunderstandings may be less likely to occur. This can be explained by the higher amount of *knowledge* available to familiar group members of other member's skills, expertise and communication styles (Adams et al., 2005). Familiar group members may share a social history, making it easier to understand each other and know each other's strengths and weaknesses. Similarly, familiarity may decrease the need for extensive regulation and coordination of task and group processes. Consequently, a third hypothesis will also be investigated.

H3 Group member familiarity will influence collaborative activities. More specifically, transfer of information, regulation of task and group processes, and misunderstandings will decrease, while indications of understanding will increase.

Group performance

In light of the above, it is likely that the increased knowledge of group members' skills and modes of interaction will help familiar groups outperform groups of strangers. For example, familiar groups will experience less process loss (e.g., misunderstandings) and be more inclined to pool information resources to effectively carry out the group task (Gruenfeld et al., 1996). Furthermore, if H1 is true, then familiar groups may hold more critical and exploratory group norms, which help them engage in *argumentative interactions*. Finally, collaboration may be more efficient because familiar groups do not need to devote as much time to regulating and coordinating task and group processes. Therefore, this study will address a fourth and final hypothesis:

H4 Group member familiarity will increase group performance.

Method and Instrumentation

Participants

The participants were students who came from five different history classes from two secondary schools working in small groups. The total sample consisted of 105 eleventh-grade students (47 male, 56 female). The mean age of the students was 16.17 years (*SD* = .57, *Min* = 15, *Max* = 18). The participants were randomly assigned to 35 different 3-person groups. It is important to note that students were assigned to groups *within their own class* and did not collaborate with students from other classes or schools.

Tasks and materials

CSCL-environment: Virtual Collaborative Research Institute

Group members collaborated in a CSCL-environment called *Virtual Collaborative Research Institute* (VCRI, see Figure 1), a groupware program designed to support collaborative learning on inquiry tasks and research projects. VCRI has been used in several research projects (Janssen, Erkens, & Kanselaar, 2007). Students used VCRI to communicate with each other, access information sources, and co-author texts and essays. Teachers also used the program to monitor online discussions and student progress. While working with VCRI, students share several tools, such as a *Sources*-tool which contains information sources that students can use to gather important information, a *Chat*-tool for synchronous communication with group members, a *Cowriter* for shared word processing, which students can use to simultaneously compose their texts or answers, and a *Diagrammer* for making external representations of ideas or arguments. Other tools not shown in Figure 1 include a *Planner* and a *Logbook*.

Inquiry group task

Participants worked on a historical inquiry task on "The first four centuries of Christianity". The task consisted of three parts. First, the groups had to answer four different questions using 12 different historical sources. To complete the second part of the task, the groups had to study 40 different information sources and categorize them into five different categories. Students had to decide together on which categories they would use. This categorization had to be visualized in a diagram, using the VCRI-diagrammer. Finally, they had to co-write an essay of at least 1200 words. The essay had to explain why and how Christianity developed from a small ‘cult’ into the main religion of the Roman Empire. In sum, the group task was an open-ended task, without a standard procedure and with no single correct answer.

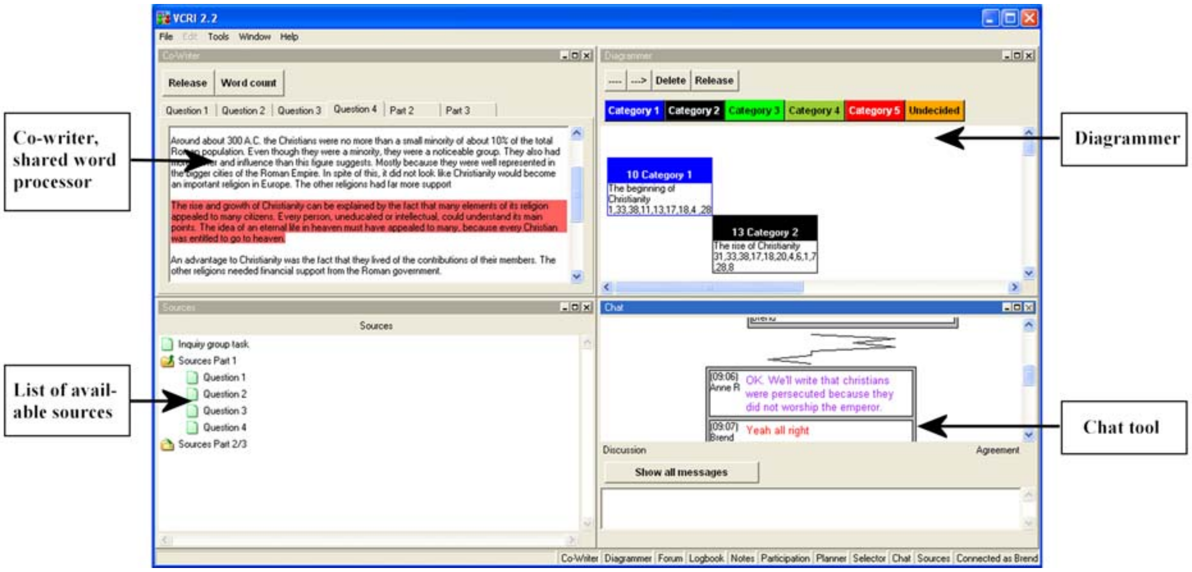

Figure 1. Screenshot of the VCRI-program.

Procedure

In total, students devoted eight, 50-minute lessons to the inquiry task. During the lessons, each student worked on a separate computer in a computer lab. Before the first computer lessons, students received information about the task and the group composition. Furthermore, students completed a pretest questionnaire, requesting personal information (e.g., age, gender) and which asked them about how familiar they were with the other group members (see Independent measure section below). During the computer lessons, teachers were standby to answer task-related questions. In addition, students were allowed to work on the inquiry group-task during their free periods in the schools’ media centers. After the last lesson, a posttest questionnaire was administered containing items on group norm perception and perception of online collaboration. Students expressed their opinions using a 5-point scale ranging from 1 (= completely disagree) to 5 (= completely agree).

Independent measure: Familiarity

Students’ perceived familiarity with the other group members served as the independent measure for this study. Based on work by Gruenfeld et al. (1996) and Adams et al. (2005), familiarity was measured by asking each student, *before the start of the collaboration*, to rate his or her two other group members on a 4-point scale, ranging from 1 (= do not him/her know at all) to 4 (= know him/her very well). This question was preceded by four specific ‘yes/no’ questions designed to remind students of situations which they had previously encountered with the other group members in order to help them better judge group member familiarity. Subsequently, the two ratings for each group member were summed to create an *overall familiarity score*, which reflected the level of familiarity of the individual student with his or her group members. Thus, the familiarity score could range from 2 to 8.

Sometimes however, group members disagreed as to how well they thought they knew each other. These disagreements may undermine the reliability of the familiarity measure. Therefore, group members’ familiarity ratings of each other were compared. An agreement percentage of 64% was found (Cohen’s $\kappa = .50$). However, this interrater reliability is a strict measure of reliability, because differences of one point (e.g., one student rated his familiarity with the other with a three, while the other gave a four) are considered disagreements. Therefore, we computed a correlation between students’ familiarity ratings of each other. This correlation between familiarity ratings of group members was highly significant ($r = .79$, $p < .01$), which shows that there was consistency between group members’ familiarity ratings. This also points to an adequate reliability of the familiarity measure. Additionally, the validity of the familiarity measure was examined by correlating the sum of the four ‘yes/no’ questions (higher scores reflect higher familiarity) with the familiarity measure. A significant correlation was found ($r = .70$, $p < .01$). This provides evidence for the validity of the overall familiarity score.

Dependent measures

Questionnaire data

To investigate hypotheses 1 and 2, data from the posttest questionnaire were used. The questionnaire contained three scales for group norm perceptions, and three scales for perception of online collaboration, which are summarized in Table 1. All of the scales had adequate reliability coefficients. Thus, for all scales students' ratings on the individual items were averaged to create a mean score.

Table 1: Summary of the scales in the posttest questionnaire.

H_n	Scale(s)	Description	Items	α
1	Critical group norm perception	Based on Postmes et al. (2001): Were students critical of each other?	3	.85
	Consensual group norm perception	Based on Postmes et al.: Was there mostly consensus in the group?	3	.60
	Exploratory group norm perception	Based on Wegerif et al. (1999): Were discussions constructively critical?	7	.73
2	Positive group behavior	Behaviors such as equal participation, helping, etc. Higher scores reflect more positive group behavior.	7	.83
	Negative group behavior	Behaviors such as conflicts and free riding behavior. Higher scores reflect more negative group behavior.	5	.66
	Perceived effectiveness of group task strategies	Choices made and strategies chosen to complete group task.	8	.81

Collaborative activities

To examine the influence of familiarity on collaborative activities, a coding scheme (Janssen et al., 2007) was used to gain insight into the task- and group-related processes carried out during students' online collaboration. The scheme contained four dimensions: task-related activities, regulation of task-related, social activities, and regulation of social activities. Each dimension contained two or more coding categories. Furthermore, the scheme included several additional categories (e.g., technical aspects) that did not belong to any of the four dimensions. In total, the scheme consisted of 19 categories. Table 2 shows all coding scheme codes. Two researchers determined the interrater reliability of the coding procedure, by independently coding 796 collaborative activities. The overall Cohen's κ was .94. The category Kappas (Cicchetti, Lee, Fontana, & Dowds, 1978) are also given in Table 2.

Group performance scores

To measure the effect of familiarity on group performance, an assessment form was developed for each part of the inquiry task. The assessment form for the *first part* addressed (1) *conceptual content and quality of argumentation* of the answers, and (2) *quality of the presentation* of the answers. *Conceptual content and quality of argumentation* were assessed using one item on a 4-point scale. *Quality of the presentation* was assessed using five items (e.g., correctness of the language used, structure of the written answer) that were rated on a 3-point scale. The assessment form for the *second part* of the task part consisted of three items which assessed the quality and completeness of the *constructed diagram* and the quality of the *explanation*. These items were also rated on a 3-point scale. For the *last part* of the inquiry task, group members needed to collectively write an essay. Comparable to part one, *conceptual content and quality of argumentation* were assessed using three items rated on a 3-point scale. *Quality of the presentation* of the essay was assessed using five items on a 3-point scale. This was done in a similar fashion as for part one of the inquiry task. To check the objectivity of the assessment procedure, two researchers scored seven inquiry tasks. The results of reliability analysis were satisfactory, as Cohen's κ ranged from .73 to .90.

Table 2: Collaborative activities (abbreviation) and category Kappas (κ_c).

	Task-related activities		Social activities	
	Codes	κ_c	Codes	κ_c
Performance	• Info exchange (*TaskExch*)	.93	• Greetings (*SociGree*)	.97
	• Asking questions (*TaskQues*)	.86	• Social support (*SociSupp*)	.90
			• Social resistance (*SociResi*)	.91
			• Mutual understanding (*SociUnd+*)	.94
			• Loss of mutual understanding (*SociUnd-*)	.87
Coordination / regulation	• Planning (*MTaskPlan*)	.94	• Planning (*MSociPlan*)	.88
	• Monitoring (*MTaskMoni*)	.93	• Monitoring (*MSociMoni*)	.96
	• Positive evaluations (*MTaskEvl+*)	.78	• Positive evaluations (*MSociEvl+*)	1.00
	• Negative evaluations (*MTaskEvl-*)	.91	• Negative evaluations (*MSociEvl-*)	-
Other	• Neutral technical (*TechNeut*)	1.00	• Other / nonsense (*Other*)	1.00
	• Negative technical (*TechNega*)	.89		
	• Positive technical (*TechPosi*)	1.00		

Results

Group norm perception

Table 3 shows the means and standard deviations of familiarity and the three measures of group norm perception, and their intercorrelations. As can be seen from this Table, students reported an average familiarity ($M = 4.24$, $SD = 1.48$) with their group members. Furthermore, familiarity correlated significantly with several dependent variables.

Table 3: Means, standard deviations, and intercorrelations for familiarity, group norms, and perceptions of online behavior ($N = 88$).

	M	*SD*	1	2	3	4	5	6	7
1. Familiarity [a]	4.24	1.48	--	.13	.14	$.27^{*}$	$.28^{**}$	$-.28^{*}$	$.26^{*}$
Group norm perceptions									
2. Critical [c]	3.25	0.75		--	$.34^{**}$	$.41^{**}$	$.30^{**}$	-.01	$.30^{**}$
3. Consensual [c]	3.50	0.62			--	$.68^{**}$	$.68^{**}$	$-.34^{**}$	$.55^{**}$
4. Exploratory [c]	3.71	0.53				--	$.76^{**}$	$-.42^{**}$	$.65^{**}$
Perception of online behavior									
5. Positive [c]	3.79	0.57					--	$-.61^{**}$	$.81^{**}$
6. Negative [c]	2.40	0.67						--	$-.57^{**}$
7. Group task strategies [c]	3.60	0.60							--

Note [a] $N = 101$. [b] Scores along a scale from 2 to 8. [c] Scores along a scale from 1 to 5. $^{*}p < .05$. $^{**}p < .01$.

Because the data were nested (i.e., students worked in groups), and because there was interdependence between group members' scores (i.e., group members could influence each other) multilevel analysis was used to examine the effects of familiarity (Kenny, Kashy, & Cook, 2006). The results of these analyses are summarized in Table 4. The β- and t-values show that familiarity had a significant positive effect on students' perceived critical and exploratory group norms. Students who knew their other group members well, reported higher perceived critical and exploratory group norms. No effect was found for familiarity on consensual group norm perceptions.

Table 4: Multilevel analyses of the effect of familiarity on group norm perceptions and perceptions of online behavior.

	β	SE β	t	χ^2
Group norm perceptions				
1. Critical	0.094	0.061	1.54^{*}	4.82^{*}
2. Consensual	0.061	0.048	1.27	5.82^{**}
3. Exploratory	0.100	0.039	2.49^{**}	10.60^{**}
Perception of online behavior				
4. Positive	0.103	0.044	2.35^{**}	10.09^{**}
5. Negative	-0.125	0.048	-2.60^{**}	13.09^{**}
6. Effectiveness group task strategies	0.105	0.046	2.26^{**}	6.45^{**}

$^{*}p < .05$. $^{**}p < .01$.

Fragment 1: Low familiarity group (line number, student ID, chat message).

1	105	I think those 4 sub questions are good. So they are definitive?
2	105	OK I'm going to think along with you guys
3	104	Which conflicts and differing opinions were there within the Christian community?
4	104	Yeah sounds okay.
5	106	Hmm, that last one is kinda difficult, because the sub questions have to relate to the main question.
6	104	Those first 5.
7	104	Yeah, right.
8	104	How did the conflicts within Christianity influence its development?
9	104	Or something like that
10	106	Yea, perfect! :D
11	104	Ok.
12	104	Wait a minute…
13	105	That will be the fifth.
14	104	I'll sum it all up.
15	104	1) How did Christianity originate and how did it develop? 2) Why did pagans convert to Christianity? 3) What are the principles of Christianity? 4) What kinds of persecutions did the early Christians suffer and why? 5) How did the conflicts among Christians influence its development?
16	106	Nice!

The two fragments illustrate these differences between low and high familiarity groups. The first fragment below shows a low familiarity group discussing questions they are going to address in their essay. As can be seen, each time a student proposes a question (lines 3, 8, and 15), this is quickly accepted by the other students. In contrast, in fragment 2 the group members are constantly critical of each others' proposals (e.g, lines 6, 8, 10, 13, and 17). These fragments illustrate the abovementioned finding that in high familiarity groups, students adhered to more critical and exploratory group norms. In summary, there seems to be sufficient evidence to support *H1*.

Fragment 2: High familiarity group (line number, student ID, chat message).

1	113	Ok, lets start
2	115	W8 a minute
3	113	:P
4	114	:D
5	115	We should first make those 5 categories, right?
6	113	Shouldn't we decide on them while reading?
7	113	Like, you could think of them then.
8	115	Yeah, when you decide on a category based on 1 source, the rest may not fit within that category.
9	115	If we just think of 5 categories, we can divide all sources over those five.

10	113	But right now we do not have a clue what they are all about?
11	115	Christianity?
12	114	Sharp… reeeeally sharp!
13	113	No, I think we better discuss those categories after we read it all.
14	115	But then you have to remember 13 sources.
15	115	How we'll categorize them?
16	114	OK, but how are we going to categorize it?
17	113	Yeah, but can't you just think of 5 while reading?
18	114	This sucks!

Perception of online collaboration and communication

The effect of familiarity on group members' perceptions of their online behavior is also reported in Table 4. Familiarity had a significant positive effect on both perceptions of positive group behavior and perceived effectiveness of group task strategies. Thus, students who are familiar with their fellow group members perceive their collaboration as more positive and rate their group task strategies as more effective. Furthermore, familiarity was found to have a significant negative effect on perceptions of negative group behavior. This indicates that in familiar groups, students report less negative group behavior. In sum, these findings support *H2*.

Collaborative activities

When analyzing the effect of familiarity on students' collaborative activities, two predictors were added to the multilevel model. In addition to familiarity, the number of chat messages typed was also included in the model to account for the fact that some groups typed more messages than others. By including this predictor, the effect of the familiarity could be investigated independent of number of messages typed by students. Familiarity was found to be a significant predictor for several collaborative activities. On the one hand it had significant positive effects on (a) social support (*SociSupp*, $\beta = 1.72$, $p = .05$), and (b) social resistance messages (*SociResi*, $\beta = 1.61$, $p < .00$). In contrast, familiarity led to significantly less (a) task-related questions (*TaskQues*, $\beta = -0.78$, $p = .04$), (b) monitoring of task activities (*MTaskMoni*, $\beta = -1.99$, $p = .01$), (c) positive evaluations of task activities (*MTaskEvl+*, $\beta = -0.59$, $p = .03$), (d) greetings (*SociGree*, $\beta = -1.30$, $p = .00$), and (e) messages indicating loss of shared understanding (*SociUnd-*, $\beta = -0.75$, $p = .03$). These results are mostly in line with *H3*.

Group performance

To examine the last hypothesis, each group received performance scores for the different parts of the group task. Since these scores were given for the *entire group*, familiarity ratings also needed to be aggregated to the group-level by summing the familiarity ratings that each student gave to his or her group members. These aggregated familiarity ratings were subsequently used as a predictor for group performance. Because in this case, both variables were at the same level, namely the group-level, ordinary regression analyses were used instead of multilevel analyses. The results of the regression analyses are given in Table 5. As can be seen, no significant effects of familiarity on group performance were found. Thus there seems to be no evidence to support *H4*.

Table 5: Regression analyses of the effect of familiarity on group performance.

	B	*SE B*	β
Part 1			
• Conceptual content and argumentation	-.01	.02	.10
• Presentation	-.02	.01	-.25
Part 2	-.04	.03	-.21
Part 3			
• Conceptual content and argumentation	-.02	.04	-.01
• Presentation	-.02	.03	-.11

$^{*}p < .05$. $^{**}p < .01$.

Conclusions and discussion

This study investigated the effect of familiarity on CSCL. The results indicate that familiarity influences several aspects of online collaboration. Because familiar group members may be more comfortable expressing their disagreement with their teammates, it was expected that higher familiarity would be associated with more critical and exploratory group norm perceptions (*H1*). This was confirmed. Furthermore, because it was expected that familiar groups would communicate and collaborate more fluidly and efficiently, more positive perceptions of the online communication and collaboration process were also anticipated. Indeed, our analyses confirmed that higher levels of familiarity were associated with more positive perceptions and less negative perceptions (*H2*). Also, familiarity was expected to influence students' collaborative activities (*H3*). Indeed, some expected effects were found. For example, higher familiarity was associated with fewer task-related questions, possibly due to the fact that communication is more efficient in those groups. Also, students who reported high levels of familiarity devoted less time to monitoring task-related activities. Again, this may be explained by the fact that coordination and communication and collaboration are more efficiently performed in familiar groups. This is also supported by the fact that students in familiar groups sent fewer messages indicating a loss of shared understanding, for example because there were fewer communication problems and ambiguities. On the other hand, familiar group members also exchanged more messages containing a negative accent. This may again be caused by the fact that group members are more comfortable communicating with each other, and are thus also more likely to voice negative opinions (Gruenfeld et al., 1996). This finding mirrors the finding by Smolensky et al. (1990) that familiarity tended to increase negative speech. It is, however, interesting to note that in familiar groups positive messages were also sent more often. The last hypothesis (*H4*) addressed the influence of familiarity on group performance. However, no effect on performance was found. This is surprising, because familiar students reported more critical group norm perceptions, perceived the collaboration more positively, and needed to devote less effort to coordination and asking questions. This may be explained in several ways. First, familiar students also engaged in negative interactions more often, which may have had a counterproductive effect. These negative interactions can undermine group climate and group collaboration, ultimately resulting in a decreased group performance. Previous research seems to confirm this assumption, as Wilson, Straus, and McEvily (2006) found that negative interactions decreased trust among group members, while Smolensky et al. (1990) found a negative relationship between negative interactions and group performance.

Several limitations of this study should be kept in mind. First, this study was set up as a quasi-experiment. Students were not assigned to either low or high familiarity conditions based on students' ratings of all of their classmates. Rather, they were first randomly assigned to groups before their familiarity with each other was established. This resulted in a somewhat skewed division of low versus high familiarity groups (8 groups of three strangers, 19 groups with one familiar relationship and two stranger relationships, 3 groups with two familiar relationships and one stranger relationship, and 5 groups consisting of three students who were all familiar with each other). This skewed division may have had an impact on our results. Second, students in this study were 15 to 18 years old. At this age, students may be sensitive to social and peer factors (c.f., Leaper & Smith, 2004), which may influence the impact of familiarity. Older or younger students may behave differently in familiar or unfamiliar settings. Third, an effect of familiarity on critical and exploratory group norms *perceptions* was found. This study did not investigate in depth whether students' online discussions also reflected these group norms. In other words, students *perceived* their discussions to be more critical and exploratory, but we do not for sure know if this actually was the case. If there is a difference between students' perceptions and actual behavior (e.g., students report they are more critical, when in fact they are not), this may be an additional explanation for why no influence of familiarity was found on group performance. On the other hand, we were able to provide collaboration fragments that illustrated the expected differences between low and high familiarity groups. This may also help to explain why familiar groups did not outperform unfamiliar groups. In sum, the mentioned limitations emphasize the need for additional research into the possibly differential effects of familiarity.

The goal of educational innovation is to make learning more efficient so that learners learn the same amount of material in a shorter time span, and/or make learning more effective so that learners learn more in the same time span, and/or make learning more enjoyable such that the affective learning experience is pleasing and learners will want to learn (Kirschner, 2004). Educational research in general and CSCL-research in particular tend to focus on determining how specific tools, environments, or student characteristics affect either the effectivity and/or efficiency of online collaboration. In the research reported here, although familiarity was not found to have an effect on group performance, it still had very important positive consequences for the way students collaborated in a CSCL environment. Familiarity clearly led to a more enjoyable collaborative experience among group members. When composing online groups, familiarity of group members should therefore definitively be taken into account.

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Online visualization of agreement and discussion during computer-supported collaborative learning

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Abstract: This paper describes the *Shared Space* (SS), a tool that visualizes discussion and agreement during online discussions by analyzing students' chat messages. The SS therefore provides group members with feedback about the way they are conducting their online discussions. It is hypothesized the SS will increase the media richness of the CSCL-environment, stimulates critical and exploratory group norms, leads to more positive perceptions of online collaboration, and will have an impact on students' collaborative activities.

Introduction

To connect to the developments in our society, teachers and students are increasingly using ICT to facilitate learning of various subjects. Computer-supported collaborative learning (CSCL) is one application of ICT that has received considerable attention by educational researchers. When students work together in a CSCL-environment, they usually use text-based CMC to communicate with their group members. Because CSCL often involves working on complex, even "wicked" problems, students need to engage in complex interactions. Thus, the problems group members may experience during online collaboration, may pose a serious threat to the effectiveness of CSCL. Furthermore, several researchers have noted that it is difficult for students to engage in argumentation: often their discussions are not critical (e.g., counterarguments are not given, c.f. Munneke, Andriessen, Kanselaar, & Kirschner, 2007) and/or not constructive (e.g., conflicts arise, c.f. Hobman, Bordia, Irmer, & Chang, 2002). Again, this may hamper online learning.

Communication difficulties and absence of critical but constructive discussion

The communication problems found during CSCL may be due to the medium itself. Traditional text-based CMC systems, such as chat, are seen as media that are low in *media richness* (Daft & Lengel, 1986). Media richness is defined as a medium's ability to facilitate communication and the establishment of shared meaning. Factors such as the ability of the medium to transmit multiple cues (e.g., facial expressions, intonation of voice), and the immediacy of feedback influence its media richness. As media richness decreases, students will have more difficulties conveying their opinions and will have more difficulties determining the meaning of group members' messages. Furthermore, when working on group tasks students usually work on complex problems without demonstrably correct answers, which require them to resolve differing viewpoints. The type of communication usually used during CSCL, may not be suited to the types of tasks group members work on (Mennecke, Valacich, & Wheeler, 2000). The low media richness of CSCL-environments may constrain collaboration in such a way that it does not transmit the type of communication that group members need to solve their task successfully. This may lead to communication problems and decreased task performance.

During online collaboration, group members should ideally engage in discussions that are critical, but also constructive. This means that group members are critical of their own and the other group members' ideas, that criticism is accepted, and explanations are given. These types of discussions have been called exploratory discussions and have been found to enhance learning during group work (Wegerif, Mercer, & Dawes, 1999). However, research has shown that students rarely give arguments and counter arguments during collaboration (Hightower & Sayeed, 1995).

This absence of critical but constructive discussion may be explained in several ways. First, students may not know how to conduct such discussions and may not posses the necessary skills. Second, as stated above, students may find it difficult to conduct constructive debates in a CSCL-environment and may have difficulties interpreting discussions, due to the lower media richness of the environment. For example, they may not know whether group members agree or disagree with them. This possibly hampers argumentation and discussion. Finally, groups may possess group norms that stimulate consensus among group members, instead of critical or exploratory discussion. In conclusion, the relative absence of critical discussion during CSCL may have different causes. These causes need to be addressed in order to facilitate critical but constructive discussions during CSCL.

Adressing communication and discussion problems using visualizations

This section describes how visualizations of online dialogue may help address the previously described communication problems and the relative lack of critical but constructive discussion. Several researchers noted the lack of social cues of CSCL-environments. For users of chat rooms or discussion boards, it is often very difficult to quickly determine who the participants of online discussions are, or what the social norms of the online group are. This lack of awareness may constrain social interaction. To address this problem, researchers have turned to visualization techniques that visualize important social features of the environment (e.g., Donath, 2002). It is expected that by using such visualizations, social awareness can be increased, which may in turn lead to more productive interaction. Therefore, a visualization called *Shared Space* (SS) was developped. It visualizes whether group members are agreeing or disagreeing about a topic during online discussion. This visualization has been implemented in an existing CSCL-environment, called *Virtual Collaborative Research Institute* (Janssen, Erkens, & Kanselaar, 2007). The SS is an extension of the *Chat tool* of the VCRI-program. The SS analyzes all messages entered in the Chat tool. Figure 1 shows a screenshot of VCRI's Chat tool with SS visualization.

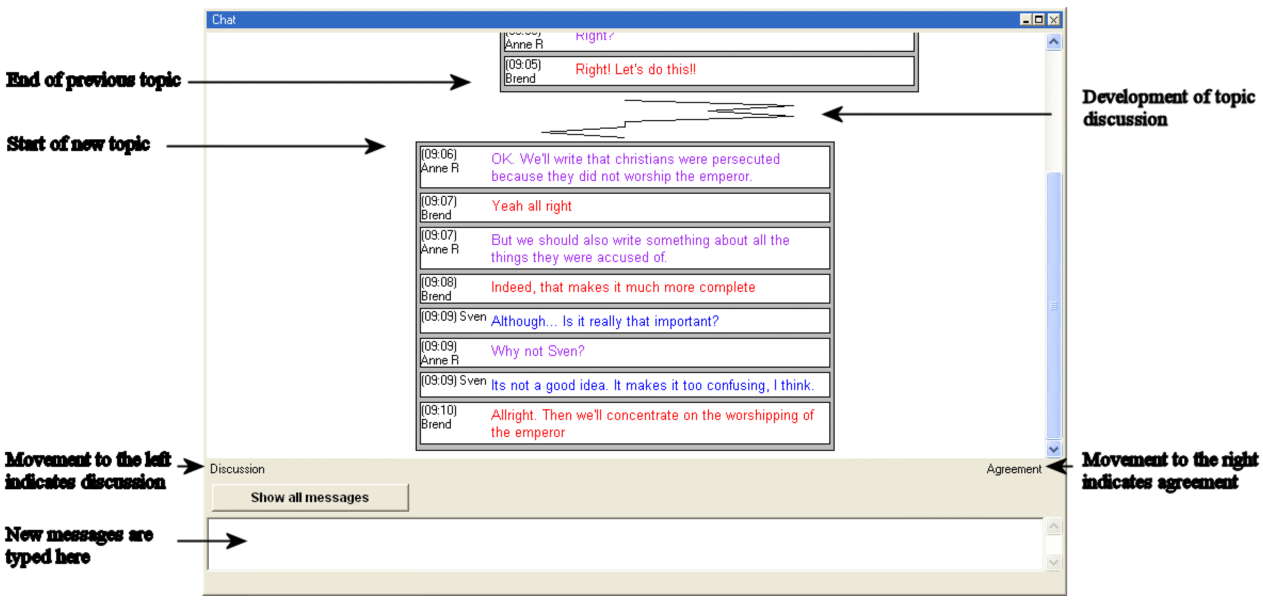

Figure 1. Screenshot of a chat window with Shared Space visualization.

First, the SS tries to determine whether a new topic or discussion has started. A new topic starts when no chat messages have been entered for more than 60 seconds. If that is the case, the current topic is ended. When a new message is entered, this marks the start of a new topic. Figure 1 shows how this is visualized in the SS. Second, the SS analyzes the content of each chat message in order to determine whether it indicates discussion or agreement. For this purpose, the SS determines the communicative function of the message. This is done using the *Dialogue Act Coding (DAC) filter* (Erkens & Janssen, 2006). This filter uses over 1300 rules based on discourse markers to determine the communicative function of a chat message. Discourse markers are characteristic words or phrases signaling the communicative function of a message (Schiffrin, 1987). In total, five main categories of communicative functions are distinguished. Each category consists of several subcategories, 29 in total. Of these, confirmations, acknowledgements, and positive evaluations are considered indications of agreement, while denials, verification questions, negative evaluations, and counterarguments are considered indications of discussion or debate. The reliability of the DAC filter was tested and found to be acceptable (Erkens & Janssen). Finally, after establishing whether the message indicates discussion or agreement, the SS moves the current topic to the left or to the right in small steps (see Figure 1). When a message indicates discussion, the SS moves the topic to the left; when it indicates agreement, the SS moves the topic to the right. This is alo reflected by the lines above the topic, which visualize the development of the current topic. These lines show that at the beginning of the depicted discussion, group members seemed to be in agreement (c.f., the first two messages by Anne R. and Brend), later on students started challenging and questioning each others' ideas and the topic moved to the left (c.f., the three messages at 9:09 by Sven and Anne R.).

It is hypothesized that the SS visualization will help group members overcome the communication and discussion problems described above for several reasons. First, the SS may increase the media richness of the CSCL-environment. Because the SS visualizes discussion and agreement, it may be easier for students to determine the meaning of messages. Additionally, it may be easier to identify the different views and positions held by group members. Moreover, the SS may help group members to determine whether there is shared understanding about a topic. Second, the SS provides group members with feedback about the manner in which they are conducting their discussions. For example, when the SS keeps moving to the right, this tells group members they may be engaged in an uncritical discussion. Thus, the feedback provided by the SS visualization may increase students' awareness about their conversational strategies and their group norms. Finally, by providing them with feedback and raising their awareness, the SS may help students perform group processing activities. This occurs when group members discuss how well their group is functioning and how group processes may be improved. During these discussions group members may be stimulated to adopt more critical or exploratory group norms. In conclusion, it is expected that SS visualization may address some of the communication problems that occur during CSCL, and may help group members to collaborate and discuss more productively.

Conclusion

This paper described the Shared Space (SS), a tool that visualizes whether group members seem to agree or disagree during their online chat sessions. The SS provides students with feedback about whether they are conducting valuable discussions (e.g., not overly critical and not too uncritical). It is hoped that by giving students such feedback, they will adapt their online behavior if necessary. The SS has been tested in a research experiment (Janssen et al., 2007), and the results indicate that the SS seems to make it easier for students to know whether their group members are agreeing or disagree with them. Furthermore, it seems to stimulate students to adopt critical group norms, instead of consensus group norms. Finally, the SS has been found to influence students' online collaboration, by reducing the amount of effort group members had to devote to reaching and maintaining mutual understanding.

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The Socio-Technical Process of Newcomer Participation: Lessons from a Field Study

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Abstract. Newcomer participation is fundamental to most organizations yet we have limited understanding of how this process unfolds in real world organizations. In this paper I present preliminary findings from a field study of five newcomers in a research and development laboratory. The findings show that to move from peripheral to full participation newcomers make use of both interpersonal and technological resources available within the organization. In addition to these resources, newcomers' participation trajectories depend on experiences that they bring with when they enter the organization. These experiences provide templates that influence and shape consequent participation. The findings also suggest that as newcomers participate in a community they influence oldtimers as well as established practices in that community, suggesting that a community of practice undergoes changes as a result of newcomer participation.

Introduction

Although work in situated learning and community of practices paradigm has been extremely influential and well-cited, we know very little about how newcomers *actually* participate in a community of practice and what situated learning in a real world organization entails. In their work Lave and Wenger (1991) provide secondary analysis of several studies to show that learning is situated within a community and can actually be called "learning to participate." We are told that newcomers learn by "experience" but not what learning by experience entails. Several questions remain unanswered: What role does the experience newcomers bring with them play in their participation? Do newcomers influence practices within the community? Moreover, given the technology pervasive nature of today's workplaces, what role does technology play in participation?

Newcomers are essential for any organization and their successful participation determines their performance, turnover, motivation, and overall productivity and innovation in an organization. Empirical literature on how newcomers become part of an organization comes from literature in the 'management' and 'organizational studies' field and usually focuses on two aspects related to newcomers: socialization (Ostroff & Kozlowski, 1992; Van Maanen & Schein, 1977) and assimilation (Miller & Jablin, 1991). Studies in these streams focus primarily on how newcomers proactively seek information and how information acquisition leads to formation of social relationships and assimilating in the work environment. Newcomers essentially use information to make sense of the new world they are in and they generally look for what, how and whom kinds of information which they acquire by observing, monitoring, or asking others (Louis, 1980; Morrison, 1993).

My conception of newcomers departs from an information acquisition and use perspective and encompasses *participation* as the core of what newcomers do. This conception is derived from the literature on communities of practice which emphasizes that becoming a part of the community is what newcomers primarily do. Newcomer participation and movement from peripheral to full participation is a fundamental process within any community of practice (Brown & Duguid, 1992; Lave & Wenger, 1991; Wenger, 1998). Accordingly, newcomers not only need to socialize and be assimilated but have to become a participating member of a community. Despite the popularity of the communities of practice concept, few studies have looked at how newcomers actually participate and what role, if any, does technology play in this process. In this paper I present preliminary findings based on a 5-month ethnographic study of 5 newcomers on how they become members of a community of practice and their engagement with technology during this process.

Field Study: Setting and Methods

The data reported in this paper are part of a larger study that involved an in-depth investigation over a period of five months of an R&D laboratory which I will call TechLab. TechLab does research in the area of software and hardware technology and has offices in the U.S. and Asia. The researchers in TechLab constitute a community of practice as they have common concerns and passions and draw on a shared repertoire of artifacts and events for participation (Wenger, 1998). Data were collected using interviews, observations, surveys, and diaries. For this particular paper a sample of 5 newcomers, who were all hired as fulltime researchers, was chosen and examined in-depth. Interviews were conducted with the newcomers at the time of joining and follow-up interviews were conducted three months later. Newcomers were observed as they participated in different practices and I conducted informal conversations with them about their participation between the two formal interviews. I also took observation notes in meetings and other activities of the lab in which they participated. In my first interview with the newcomers I asked them about their background including previous work experience and education; their day-to-day work at their current job; interaction with their mentors; future plans; their experiences so far at this job; their expectations in the coming weeks/months; their interactions with their colleagues; and their job interview process. Subsequently, I asked each newcomer to keep a diary for a week. In this diary I asked them to note their interactions with a coworker, which was decided in advance, including the medium of interaction as well as the content. I also asked them to record if this interaction was significant for them in some way. In the follow-up interview, in addition to asking them about their experiences at the job I also asked them questions about particular interactions they had listed in their diaries. I was also able to observe their interaction in meetings and their contributions to websites and other technologies in the workplace.

Findings

In this short paper I present an overview of newcomers' participation (Figure 1) focusing primarily on their engagement with technology. When talking about technology newcomers reported using the Intranet initially to look for information about their coworkers and for downloading documents related to travel, payroll and HR functions. In the first few weeks they reported looking at the photos on the Intranet to put faces and names together.

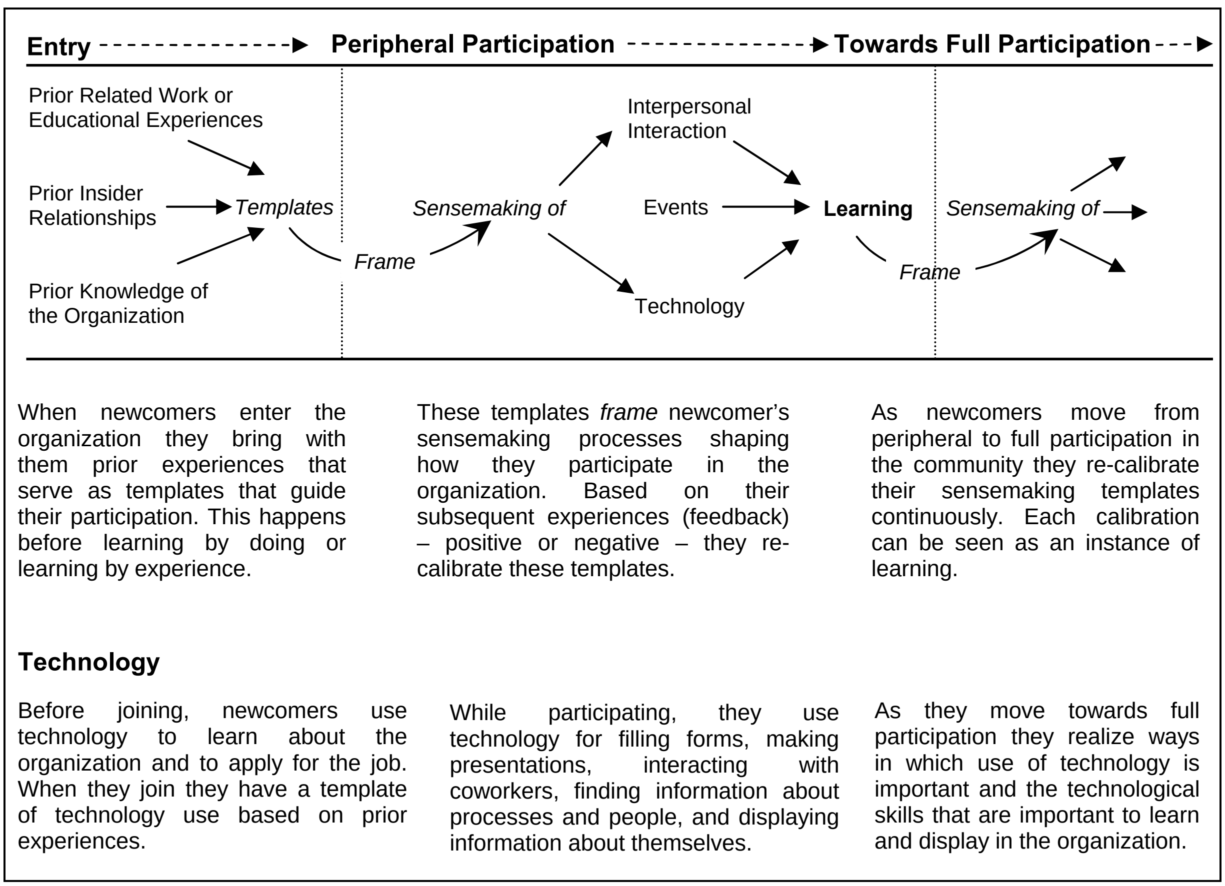

Figure 1: Newcomer sensemaking from entry to full participation

During interviews they would often pull up that page and point to a photo and say this is the person I am talking about. They used the archives to see what their coworkers had published and patented as well as to look at examples of works. Newcomers also used the archives to look at presentations they had made including their job talks to be able to improve their presentation skills. They reported that they used the Intranet to start conversations and build relationships by looking at a coworker's prior work and then going and talking to them about it. Newcomers with preexisting relationships within the organization reported using technology far less for information acquisition, both for interpersonal as well as organizational information, than those newcomers who did not know anyone when they joined. Newcomers' use of technology changed with time. Over time technology was used used to get information about artifacts and to understand how those artifacts, such as papers, demos, were produced. Technology, primarily email, was used to a large extent for communication but informants reported that technology-mediated communication complemented face-to-face interaction but did not substitute it and evidence from the diaries showed communication regarding the same topic through both email and face-to-face interaction. Newcomers reported talking to coworkers to understand how to contribute to the Intranet, since these contributions were a part of their practice. For instance, every month researchers had to write a monthly activities report which was submitted to the manager and then he put it on the Intranet. Technology use changed gradually and technology use became a practice in itself. Newcomers learned the value and meaning of technology use within the organization and started to 'engage' with technology. Proficiency in technology was seen as being able to speak the "language of the laboratory."

Implications and Discussion

Engagement with technology, which involves more than just using it for communication, is critical for newcomers to participate in a community of practice. Theoretically, this work shows that when looking at how technology affects newcomers in an organization, it is important to look at not only how they are using technology but how they are engaging with technology in different ways, including using technology as the raw material for producing artifacts and as a medium to display and present work. In addition to theoretical contribution on newcomer literature and communities of practice, there are several design implications of this work. It highlights that system designers need to pay more attention to designing systems for particular audiences in the organization keeping in mind their practices. For instance, newcomers might be an audience towards whom a system is directed and if well built that system might be adopted by others in the organization. A well designed system that serves a particular audience really well is likely to be used by others (Cooper, 2004). Given the proliferation of technology in organizations and its manifestations in different forms such as for communication, for designing work, for presenting work, for finding information about coworkers, and so on, there might be a need to fundamentally reexamine how technology has changed our relationship to work and to other people.

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Transcendent Communities

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Abstract: Online communities are potential arenas for informal and lifelong learning. Even though technology fosters internal sharing and collaboration in online communities, it also presents excessively strong external boundaries. These silo-like structures lead to fragmentation, counteracting cross-community collaboration and interdisciplinary learning. We are revising our own online community software to support a particular sociotechnical pattern: the emergence of "transcendent communities"—networks of participation that transcend collections of related but distinct communities. In order to understand such inter-community activity we have developed a theoretical analysis of the basis for individual action and how this action can lead to value for the larger community. Investigating the relationships between individual action, social affordances of the technology and group identities will help us to design for functionality and for meaning.

Introduction

Like traditional communities, online communities have their own identities, norms, and goals, and several of a community's objectives may be shared with one or more related communities. Together these communities and their purpose may benefit from sharing information, coordinating events, and collaborating towards their common goals while still maintaining their distinctions as individual communities. For example, groups in an online teacher community we support (hnlc.org) have to share with each other, yet each group needs its own virtual "place" to conduct its work. It has been challenging to provide these nested and overlapping groups with the identity and space they need while maintaining awareness and sharing of resources at all levels. A similar problem exists in postsecondary education. Students experience courses as silos, isolated from each other. Unfortunately the silo approach can inhibit the sorts of collaboration that can be most conducive to learning (Derry & Fischer, 2005). For example, students and faculty in our own interdisciplinary Communication and Information Science program (www.hawaii.edu/cis/) participate in multiple nested and overlapping groups and organizational units and are members of a larger community.[1] Yet, this fact is not well supported by current online learning environments, including our own (disCourse.ics.hawaii.edu).

Although fragmentation is part of the problem, complete unification under one identity, goal or technological space is not the solution. Even though the constituent collectives share some goals, they are likely to have additional objectives that are not shared and that make them unique. These goals are a part of each collective's identity that attracts and ties the members to the collective and that in turn makes up parts of their own identities (Tajfel & Turner, 1986). Fragmentation into smaller community sites is also a problem for large community sites (Bruckman & Jensen, 2002). The desire to maintain existing identities can prevent smaller communities from merging into larger ones. Successful coordination between communities forms only by the deliberate and dedicated effort of those who span their boundaries (Levina & Vaast, 2005).

When two or more collectives share concerns, there is potential for an alternate solution: the formation of a community that transcends formal boundaries and has greater potential to reach the critical mass (Markus, 1987) needed to achieve a new level of collective activity. This approach resolves the fundamental tension that groups need to be small and have a sense of shared intimacy, yet also need to become connected to a larger set of like-minded groups in order to progress. To achieve this, flexible technological boundaries are needed similar to those in traditional communities (Barth, 1981; Cohen, 1985) where boundary-spanning activities may take place. A balance is needed between global connectivity and distinct groups, requiring support for permeable boundaries of participation that lead to communities transcending associated collectives without violating the integrity of each collective unit. We need to overcome the tendency of technology to present stark digital boundaries that discourage communication (Postmes, Spears, & Lea, 1998).

[1] This paper uses the terms *collective* generically for social entities, *group* for networks of individuals who regularly interact (e.g., workgroups), *community* for people sharing symbolically constructed identities, and *organization* for collectives that are hierarchically structured to fill a functional need in society.

From Activity Cycles to Communities

Since transcendent communities will arise only based on the actions of individuals, it is essential to understand the basis for individual action and how it can lead to value for the community. One way of looking at individual activity is through the lens of the participation-reification duality (Wenger, 1998). In this view, acts of participation are intrinsically bound up with reifications that both frame and leave a trace of that act. When participants come across traces of previous participation, further participation may occur leading to further reification. Ideally a virtuous cycle occurs as participation levels increase along with a well-organized set of valuable resources. Figure 1 displays an activity cycle of find→care→act→persist with the various factors that affect each stage of the cycle, bridging the realms of functionality and meaning. We posit this cycle of online activity as a basis for analyzing how the confluence of participation and identity in a technological environment increases value for the community. Any participation involves a physical reification, but the persistence of that reification is a function of the medium in which it is expressed. Media may be designed to increase the likelihood of capture and persistence of individual activity as a potential source of value for others. A persistent trace of participation can become the basis for subsequent participation in a two-step process. First of all, a given reification has to be found, by accident or intent. Again, media may be designed such that past reifications are available for chance or intentional discovery, by promoting awareness and associative access. Second, given that a reification has been found by an individual, there arises the question of whether this individual will care enough to act on it. Caring critically involves identity and acting involves motivation, which are functions of the history of previous interactions. For example, if an individual encounters a reification of prior participation by a person she perceives as belonging to some shared community or having common goals, then the individual may act on this reification, continuing the cycle of activity. In summary, in order to foster interactions between individuals that will lead to collective value, this analysis guides design to ensure as best as possible that relevant reifications of activity are persisted, that these traces can be easily found, and that individuals can perceive group and individual identities associated with the reifications and their potential value so that potential participants will care enough to further participate.

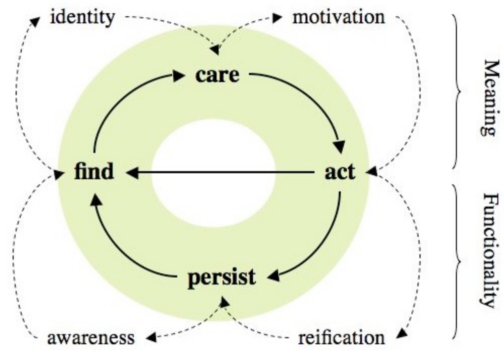

Figure 1. Activity cycle and related factors

In the ideal environment the medium and its social-technical affordances will maximize the likelihood of each of the individual processes that allow this cycle to be continued and connected across many individuals. Figure 2 shows how the persistence of reifications connects the activities of different individuals. Multiple interconnected activity cycles can lead to a group of repeatedly participating individuals who derive benefit from access to the aggregated resources, as well as occasional participants who perhaps contribute less, but benefit all the same. Given an open environment the number of participants is unlimited, as is the value that may be created. However in reality there will be pools of more tightly interconnected reifications, as there will be sets of individuals who more frequently interact with each other's reifications, creating and sustaining groups and communities.

Individuals may participate in multiple groups and perceive themselves as belonging to different degrees to multiple communities. We can see a group as a network of interacting individuals and a community as a group that is distinguished through common identity. In order to promote the creation of emergent communities we need to encourage more than just a few trajectories that go

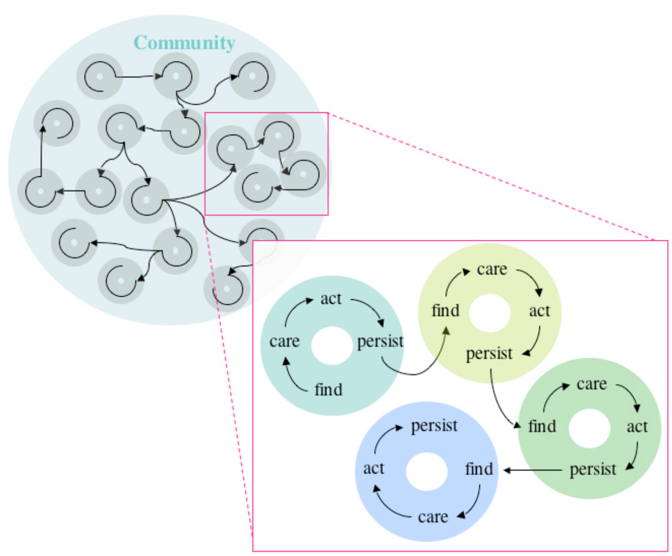

Figure 2. Persistence connecting activity cycles

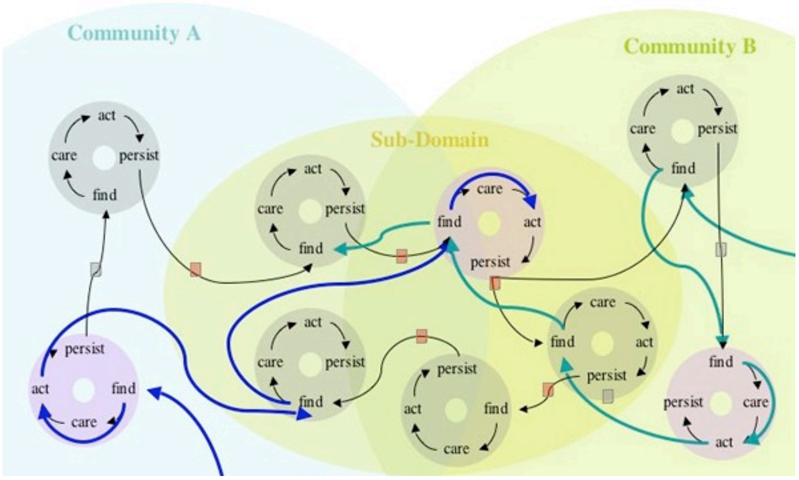

Figure 3. Pathways connecting communities

across the tight networks—we need to encourage "boundary spanning" as a natural activity. Boundary spanning can be accomplished both by the movement of individuals and the sharing of objects. Figure 3 displays the creation of a sub-domain or boundary domain between two communities as participants are enticed to participate in activity cycles involving each others' reifications.

Conclusion

New technologies are offering new potentials for collaboration, but increased connectivity must be balanced with the need for maintaining intimate communities. If transdisciplinary education is to succeed, we need to enable trans-boundary participation without posing a threat to the involved communities' identities. In order to address this we need to understand the basis for individual action, how this action can lead to value for the larger community, and how social affordances of technology can amplify both of these. The activity cycles reveal how individual action is influenced by factors of both functionality and meaning that should be addressed by design: awareness and access, portrayal of identity, goal-relevance, and conversion of activity into value for others. We can then use this understanding of individual action to bridge to the community level, investigating how sociotechnical affordances enhance or inhibit the productive entanglements between individual trajectories of activity within and across communities. Analysis of the activity cycles should help us better understand the operations of boundary spanners and boundary objects; ultimately allowing us to design sociotechnical affordances that facilitate the achievement of critical mass through multiple inter-community interactions. Our ongoing work seeks to contribute towards a general understanding of design for transcendent communities: larger spheres of common identity and social capital that arise from interactions between individuals who participate in collections of related communities.

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How Can The Design Of Educational Technologies Affect Graduate Students' Epistemologies About Learning?

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Abstract: This paper describes a course in which graduate students learn practical and theoretical aspects of educational-design. The course was enacted with 14 students in education. Outcomes illustrate tensions between students' professed beliefs about learning and their actual design practices in four dimensions that characterize the technologies they designed: *Learner-activity*, *Collaboration*, *Autonomy*, and *Content-accessibility*. By peer-negotiating of these tensions, students developed their skills to design educational-technologies and increased the coherence of their epistemological understanding.

Introduction

Although modern learning theories emphasize constructivist or socio-cultural models of learning, most instruction is still didactic. Numerous researchers have documented the resistance of educators to employ constructivist pedagogies in the classroom, even when they explicitly espouse constructivist learning theory (e.g., Maor & Taylor, 1995; Tobin et al., 1994). In this paper, we describe how a similar disconnect exists in educational-design students, and how a practice-based approach helped these students develop practices more well aligned with their espoused beliefs. Educational design is an important area of study both because of its inherent importance in producing educational materials, and also as a model for studying learning in complex domains. Yet, design is an elusive subject to teach. In traditional design fields such as architecture or graphic arts, design is taught through a studio approach in which learners examine examples, conduct lengthy design projects in the company of others doing similar projects, and proffer and receive frequent peer and expert feedback. Schön (1983; 1985), and Glaser (1996) have described this as an important way to teach design and professionalism in other disciplines, while Hoadley & Kim (2003) describe how such methods can be used in teaching educational design.

In this paper, we describe a particular course in which students learn educational design through studio methods. We show how the course format highlights tensions between students' professed beliefs about learning and their actual design practices. We also look at how the design studio format allowed students to negotiate these tensions, ultimately leading to more coherence between ideas about learning and their designs.

Context

The design of the course was based on a previous study (Ronen-Fuhrmann & Kali, 2005), which characterized graduate students' use of a Design Principles Database (Kali et al., 2004) in designing new educational technologies. One of the main findings were that students had difficulties in designing their own educational technologies due to the open-ended nature of the task; based on this finding we decided to use a more structured design process, and build the course around a model we call the design studio model. Our model for the design process builds on the well known ADDIE stages (analyzes, design, develop, implement, evaluate) (Dick & Carrey, 2001), in which we expand the *Design* stage, to include three other non-linear iterating stages: *Brainstorm*, *Build-flow* and *Design-features*. The Design Principles Database is used in four stages in this model as illustrated in figure 1.

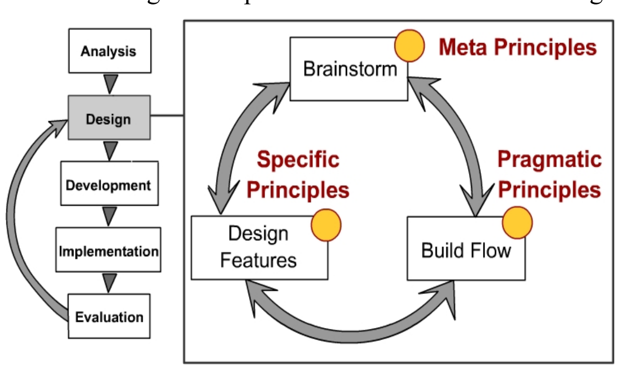

Figure 1: The Design studio model – the yellow dots indicate stages in which the design principles database is used

Methodology

The design course described above was enacted in spring semester 2005 with fourteen graduate students at the Technion. In order to characterize student learning, rich qualitative data was gathered throughout the semester. Data sources included whole class online discussions about the literature, group online discussions (for the design studio and analyzing technologies projects), student artifacts (documents produced at various stages of the in the design studio in which students designed their own educational), entries in the Design Principles Database, and a reflective diary in which we documented important events in each of the class meetings.

To analyze the data and characterize student epistemologies at various stages of the design process we developed a rubric based on two existing frameworks. The first is Reeves' framework, which includes 14 pedagogical dimensions for assessing computer-based education (Reeves, 1994). The second is the SKI framework, mentioned above, for designing web-based inquiry curricula (Linn et al. 2004). Since these frameworks do not include a rubric for quantitatively assessing the design of educational technologies, we combined and modified these frameworks to develop a rubric consisting of four dimensions: a) Learner activity, b) Collaboration, c) Content accessibility, and d) autonomy.

Outcomes

The analysis of the data indicates that most of the students expressed ideas that where categorized as "high" according to the first three dimensions of the rubric (Learner activity, collaboration and content accessibility). These expressions where found when students where engaged in face-to-face or online discussions. An example showing a high degree of the "content accessibility" dimension, in one of the first online discussions, is: "as a school teacher, I see that learning is meaningful when the context is tangible and relates to the learners' world; when I teach about the concept of pendulum in physics, I connect it to the swing at the school yard".

However, when they began designing their own technologies, many of them designed modules, in which learners have a passive role, as consumers of information, and the interaction with the technology was restricted to reading, or watching things on the computer screen. Students tended, at initial stages of their design studio project, to design environments in which users work with the technology individually, in their own pace. In addition students tended to build the flow of activities in their technologies based solely on the structure of knowledge in the domain they intended to teach. They were mainly concerned with what learners should know at each stage of the flow, and less concerned with how to make this flow engaging for the learners.

As the semester proceeded, their designs incorporated more and more components in which learners have an active role, and are engaged in construction of knowledge in interactive environments, using tools that allow them to express their ideas, manipulate elements, or build artifacts. Students tended to embed more and more social supports in their designs, and enabled their potential users to negotiate their understanding with their peers. Students became more concerned that the domain content within the technology environments, build on learners' prior knowledge, connect with their everyday lives, and engage the learners.

We view the high level of pedagogical ideas expressed by students throughout the semesters as their "theoretical epistemologies". We consider the ideas expressed by students' actual design practice as their "applied epistemologies". As apposed to the other dimensions, the autonomy dimension did not reveal a clear gap between students' epistemologies as expressed in their sayings and their doings. However, we did observe a change in students' epistemologies in this aspect throughout the course. From the beginning of the semester, many concerns were expressed by our students about the lack of control that teachers have in open-ended environments. The notion that technology (or the teacher) should monitor and control student learning was most prominent. This notion was consistent with their designs at initial stages of the design process. Many of the projects were tutorial type environments that funnel learners in different learning paths according to their performances and provide teachers with precise information of learners' progress. As the design process proceeded, students' designs increasingly included open-ended activities and tools in which learners have more flexibility in directing their own learning paths.

Discussion and Implications

This study revealed a gap in students' "theoretical" and "applied" epistemologies. At the beginning of the semester, when engaged in theoretical discourse, students tended to advocate socio-constructivists paradigms, whereas when engaged in designing technologies they tended to neglect these ideas and apply more traditional approaches. The analysis also indicated that in three of the four dimensions (learner activity, collaboration, and content accessibility) this gap was reduced during the course. Thus, as students developed their skills to design educational technologies, they also increased the coherence of their epistemological understanding.

The outcomes indicate that these advances may have resulted from various aspects of the design of the course. The three-theme structure of the course, including the, *Technology Analysis, Design Studio* and the *Theory* themes, provided a rich variety of resources that made it possible for students to learn important aspects of design. The cognitive apprenticeship model of instruction, and the supports for peer learning in the course, enabled students to take advantage of these resources, and eventually brought to widening their intuition for designing educational technologies, and to development of their epistemological understanding.

This study reveals that epistemologies that are based on theoretical understanding about various approaches in the field of education may lack coherency if they are not applied to real situations. Engaging students in design using a studio course format, proved to be a productive way for students to examine their own epistemological beliefs, negotiate them with peers and experts, and explore them in relation to theory. Such engagement can bring to expanding of students' design intuition as well as meaningfully enhance their epistemological understanding. We therefore suggest that designing curricula in a studio fashion, whether it involves technology or not, should become an integral part of the academic professional development program for graduate students in education.

To explore the generality of the outcomes, we continue to study the course in a design-based research approach, in several enactments with more students in other institutions in the United States. Data from these enactments will help examine the extent to which our current findings reflect a local situation, or are more widely spread.

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Emergence of Learning in Computer-Supported, Large-Scale Collective Dynamics: A Research Agenda

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Abstract: Seen through the lens of complexity theory, past CSCL research may largely be characterized as *small-scale* (i.e., small-group) collective dynamics. While this research tradition is substantive and meaningful in its own right, we propose a line of inquiry that seeks to understand computer-supported, *large-scale* collective dynamics: how large groups of interacting people leverage technology to create emergent organizations (knowledge, structures, norms, values, etc.) at the collective level that are not reducible to any individual, e.g., Wikipedia, online communities etc. How does learning emerge in such large-scale collectives? Understanding the interactional dynamics of large-scale collectives is a critical and an open research question especially in an increasingly participatory, inter-connected, media-convergent culture of today. Recent CSCL research has alluded to this; we, however, develop the case further in terms of what it means for how one conceives learning, as well as methodologies for seeking understandings of how learning emerges in these large-scale networks. In the final analysis, we leverage complexity theory to advance computational *agent-based models* (*ABMs*) as *part* of an integrated, iteratively-validated *phenomenological-ABM* inquiry cycle to understand emergent phenomenon from the "bottom up".

Introduction

The past few decades have seen a consistent and persistent evolution from an individualized conception of learning to a more collectivist, participatory conception (Lave & Wenger, 1991; Scardamalia & Bereiter, 2003; Hutchins, 1995). By and large, this forms the epistemological core of CSCL research (Stahl et al., 2006). Concomitantly, educational technology has also evolved from the days of individual computer-based instruction to interactive and participatory online environments; the latter ranging from small-group, CSCL environments to large-scale, multi-user, interactive environments such as 2nd Life, Wikipedia, topical online communities, etc. At the small-scale or small-group level (typically 2 - 30 people), CSCL research has made substantive progress into unpacking the interactional dynamics, though, much important work still needs to be accomplished. At the large-scale level (typically in the 100s and the 1000s), however, we understand very little of the phenomenon of how people leverage technology to come together to interact, participate, collaborate, and form emergent structures and patterns (Sawyer, 2005; Jenkins, 2006); a phenomenon hereinafter referred to as large-scale *collective dynamics*.

Indeed, one of the most intractable problems in the social sciences, in general, and the learning sciences, in particular, is how interacting groups of agents (e.g., people) create emergent organizations at the collective level that are not reducible to any individual (Epstein & Axtell, 1996; Goldstone, 2006). For example, cognition and learning emerge from a collective set of interacting neurons yet the notion of cognition is absent and incomprehensible at the neural level. Highly coordinated behavior emerges in flocks of birds yet the notion of coordination is absent at the individual bird level. Traffic jams propagate backward but they emerge from interactions between individual cars (controlled by their drivers) going forward; movement at the collective level runs in a direction opposite to that at the individual level. Social structures, beliefs, values, and norms emerge in groups of people—offline and online—that cannot be attributed to or dictated by any individual per se, e.g., communities of practice, Wikipedia, and so on.

How does such collective behavior emerge? How does learning emerge in these large-scale collectives? More importantly, how are some large-scale collectives able to adapt, learn, and persist, while others perish?

Understanding the interactional dynamics of how large-scale collectives function and perform is a critical and an open research question, especially in an increasingly computer-supported, inter-connected, media-convergent world (Jenkins, 2006). It is also a subject of increasing scientific importance given its prolific coverage in the premier scientific journals such as *Nature* and *Science* (for a review of this trend, see Goldstone & Janssen, 2005; also see the Proceedings of the National Academy of the Sciences, 2002).

CSCL researchers such as Stahl et al. (2006) and Suthers (2006) have also alluded to this. For example, Suthers (2006) argued that, "small groups should not be the only social granularity studied. For example, the emergence of social and knowledge capital in a community of practice may require tracing out the evolution of relationships and the formation and spread of ideas in networks of individuals larger than the small group" (p. 16). Notwithstanding, CSCL and learning sciences research in this area remains in its infancy (Jacobson & Wilensky, 2006; Goldstone, 2006). This is, in part, due to the focus of CSCL research primarily being on small-scale collective dynamics (hereinafter synonymous with and a referent to small-group CSCL), which, of course, is substantive and meaningful in its own right. The purpose of this paper, however, is to *extend* the CSCL research agenda by proposing a line of inquiry that seeks to understand computer-supported, large-scale collective dynamics.

Organization of the Paper

The rest of this paper is organized into five sections. In the first section, we discuss what our proposal means for how we conceive learning in small-scale versus large-scale collectives. Despite some obvious differences between the two, we argue that learning in collectives is an emergent phenomenon regardless of the scale at which the phenomenon takes place. An emergent conception necessitates that we next unpack the very concept of emergence, and this forms the second section. The third section examines existing CSCL methods to see if and how they may be used to gain understandings of emergent behavior of large-scale collectives, and whether we need to integrate existing methods with others not currently used in CSCL research. Our analysis sets up an imperative for a methodology that builds on existing CSCL methodologies and is able to capture and model emergent behavior of large-scale collective dynamics. The fourth section advances computational Agent-Based Models (ABMs) as *part* of an integrated, iteratively-validated *phenomenological-ABM* inquiry cycle to understand emergent behavior of large-scale collectives from the "bottom up." The fifth and final section concludes with directions for future research.

Unpacking Learning

A focus on collective dynamics—small-scale and large—requires that one adopt a broader conception of learning. Traditional conceptions of learning in cognitive science and educational research have tended to focus on the individual as the unit of cognition and learning; only the individual perceives, thinks, and learns. However, as mentioned earlier, the past few decades have seen a consistent and persistent evolution from an individualized conception of learning to a more collectivist, participatory conception (Lave & Wenger, 1991; Scardamalia & Bereiter, 2003; Jenkins, 2006; Hutchins, 1995). While this evolution is generally in agreement with CSCL research, a careful reading of CSCL research reveals a continuum of conceptions (for an excellent review, see Stahl, 2005).

On the one end, learning is conceptualized primarily as an individual-level construct but one that may benefit from the collaboration. On the other, learning is conceptualized primarily as a group-level construct or activity in which individuals participate and interact with each other. Between these two ends, a range of conceptions exist of which we provide a sample; it is neither our intent nor is it possible to be exhaustive here. For example, if one leverages the knowledge acquisition metaphor, one could examine individual pre-to-post intervention gains as learning. Alternatively, if one leverages the participation metaphor, one could selectively examine the nature of an individual's participation in an activity or a community of practice as learning; conceptions of *legitimate peripheral participation* (Lave & Wenger, 1991) and *internalization* (Vygotsky, 1978) can be justifiably invoked as individual learning. At the collective level, one could just as well leverage the participation and interactional metaphors to conceive learning as an emergent property arising from the productive agency that drives participation and interaction between group members, e.g., knowledge building (Scardamalia & Bereiter, 2003). The interactional metaphor could even be leveraged in the radical sense to conceive learning not as something that is constituted *through* interaction but *is* the interaction (Koschmann et al., 2005). Further, and these are perhaps less frequently invoked but just as valid, conceptions of learning at the collective level may be tied to how groups adapt and reorganize in response to changing environmental and selection pressures (Kauffman, 1995). Here, emergent organizations and structures can be conceived as collective learning; the more a group is able to reorganize in a flexible and effective manner, the more it can be seen as learning.

Our own conception of learning is grounded in the science of complexity (Kauffman, 1995). We adopt the broader conception to include cognition and learning at the collective level as well. This conception clearly falls on the abovementioned continuum but is different in the sense that the "group" is not an *a priori* entity; it emerges (sometimes) from the intersubjective interactions between individuals, and once such an organization emerges, it shapes and constrains the very interactions it emerged from. While this dialectic is at the core of our conception, complexity theory also suggests a rather clear ontological and epistemological position: both individual and group cognitions co-exist; both the individual and the group co-learn; the nature of such learning being dialectical, dynamic, and emergent (Kapur et al., 2006; Voiklis et al., 2006).

Invoking emergence, however, only begs the question: how, when, and why does collective cognition emerge? Among cognitive and learning scientists, interest in collective cognition and its emergence is a recent phenomenon (e.g. Goldstone, 2006); existing theories (e.g. Hutchins, 1995) detail how collective cognition propagates *once* structured and organized, but for a theory of its emergence which does not presuppose these structures *ab initio*, one needs to look towards complexity theory (Kauffman, 1995; Epstein & Axtell, 1996). This need also stems from the cumulative effect of empirical research indicating that intersubjective processes at the local (individual) level yield cognitions—e.g opinions (Isenberg, 1986), knowledge representations (Schwartz, 1995), among others—that differ, both in complexity and kind, from those produced by any collaborating agent or those expected from the central tendency among collaborators (Vallacher & Nowak, 2004). Moreover, these group-level cognitions emerge spontaneously, without forethought or awareness among collaborating agents (Goldstone, 2006). Apparently, both the individual and the group learn; this learning being at once distinct, dialectical, and emergent.

From the preceding paragraph, it perhaps follows that the closest match for our conception with CSCL research is in the intersubjective learning epistemology. This is because intersubjective learning (as we understand it) focuses on the process of meaning-making in the social interactions distributed across actions, actors, and artifacts. It conceives learning at both the individual and collective levels although the ontology underpinning this epistemology (e.g., is there really a collective mind? How is it possible for learning to be distributed?) is still being debated (e.g., see Stahl, 2005; Koschmann et al., 2005). Notwithstanding this ontological debate (which we maintain is healthy), we do see sufficient epistemological coherence and consistency between the complexity and intersubjective conception of learning to move the conversation forward.

Moving forward, therefore, we articulate five dimensions along which small- and large-scale collectives exhibit critical differences in how they function and perform. In turn, these differences have implications for how learning emerges in these collectives. Note that while we present these differences as analytical dichotomies, in our conception they represent more of a difference of degree than of kind. Conceiving these analytical dichotomies as continuums, the five dimensions are:

i. <u>Spatial-Temporal landscape</u>: The space (both real and virtual) and time over which large-scale collective dynamics evolve is relatively larger; individual members are typically distributed over a much larger space and the phenomenon typically unfolds over relatively longer life spans (typically months, often years). In contrast, small-scale collectives, while also distributed, are limited to a relatively smaller space (both real and virtual). Plus, their timescale or the life span is relatively shorter (typically days or weeks, sometimes months, rarely years). Thus, the spatial-temporal landscape on which the phenomenon unfolds differs to a substantive degree.
ii. <u>Open vs. Closed systems</u>: Small-scale collectives in CSCL research typically tend to be relatively *closed* systems; once the group members and the mediating tools and artifacts (including scaffolds) are set up, there are typically few, if any, additions within the spatial-temporal landscape over which the group's collaboration unfolds. Large-scale collective dynamics, in contrast, are relatively *open* systems, where the number of group members, mediating tools and artifacts, and the spatial-temporal landscape are typically co-evolutionary.
iii. <u>Level of a priori structure</u>: The level of *a priori* structure in small-scale collectives in CSCL research is relatively high; these are intentionally designed learning environments (witness the significant research efforts on the efficacy of interactional scripting and scaffolding in CSCL research). Large-scale collectives, on the other hand, are typically decentralized and less structured. This does not mean that there are no structures in large-scale collective dynamics. What it means is that many (though not all) of these structures emerge spontaneously from within than being designed for from the beginning. Of course, structures emerge in small-scale collectives as well; we do not deny this. As stated earlier, it is a matter of degree; the likelihood of such structures emerging from within is greater in the large scale collectives than small-scale ones in CSCL research.
iv. <u>Individual agency</u>: In small-scale collective dynamics, individual members have relatively less agency compared to individuals in open, decentralized, large-scale collectives. In the latter, individuals can choose to

participate and collaborate if and when they want, and interact with whomever they want. This is relatively less so in the former. This difference in individual agency is important when one considers research on the importance of productive agency in collaboration (Schwartz, 1999). Combined with the previous dimension, the structure-agency dialectic leans more towards a priori structure for small-scale collectives whereas it leans more towards individual agency for large-scale collectives, where individual agency can even result in a dynamic reorganization of collective structures. Again, this is a difference in degree, not kind.

v. Diversity: Large-scale collectives also allow for relatively greater diversity among its individual members. Such diversity is relatively low for small-scale collectives mainly because of their relatively smaller size. Lack of sufficient diversity also makes the emergence of distributions in small-scale collectives highly unlikely (e.g., consider if it is even meaningful to speak of a normal or power-law distribution in a small group)

The relatively longer-term, open systems formed by computer-supported, large-scale collectives together with lower a priori structure, higher individual agency, and greater diversity make for an exponentially greater system complexity when compared to the small-scale collectives in CSCL research. It is this very complexity that sets up the stage for the *emergence* of learning—structures, interactional patterns, participation patterns and culture, knowledge, values, norms, etc.—making large-scale collective dynamics an intriguing phenomenon worthy of inquiry in its own right. If so, it becomes necessary that we unpack the very concept of emergence first before seeking methodologies for understanding it in the context of large-scale collective dynamics.

Unpacking Emergence

The concept of emergent behavior is, however, rather paradoxical. On the one hand, it arises from the interactions between agents in a system, e.g., individuals in a collective. On the other hand, it constrains subsequent interactions between agents and in so doing, seems to have a life of its own independent of the local interactions (Kauffman, 1995). For example, a traffic jam emerges from the local interactions between individual drivers; at the same time, it constrains the subsequent local interactions between individual drivers. Traffic jams, once underway, do seem to have a life of their own. Similarly, structures within social networks emerge from the local interactions between individual actors. At the same time these structures constrain the subsequent local interactions between individual actors (Watts & Strogatz, 1998), and so on. It becomes fundamentally important to understand *how* macro-level behaviors emerge from and constrain micro-level interactions of individual agents.

Understanding the "how," however, requires an understanding of a cardinal principle in complexity: simple rules at the local level can sufficiently generate complex emergent behavior at the collective level (Bar-Yam, 2003; Kapur et al., 2006). For example, consider the brain as a collection of neurons (agents). These neurons are complex themselves, but exhibit simple binary behavior in their synaptic interactions. This type of emergent behavior, when complexity at the individual-level results in simplicity at the collective-level, is called *emergent simplicity* (Bar-Yam, 2003). Further, these simple (binary) synaptic interactions between neurons collectively give rise to complex brain "behaviors"—memory, cognition, etc.—that cannot be seen in the behavior of individual neurons. This type of emergent behavior, when simplicity at the individual-level results in complexity at the collective-level, is called *emergent complexity* (Bar-Yam, 2003).

The distinction between emergent simplicity and complexity is critical, for it demonstrates that a change of scale (individual vs. collective level) can be accompanied with a change in the type (simplicity vs. complexity) of behavior. "Rules that govern behavior at one level of analysis (the individual) can cause qualitatively different behavior at higher levels (the group)" (Gureckis & Goldstone, under review, p.1). We do not necessarily have to seek complex explanations for complex behavior; complex collective behavior may very well be explained via simple, minimal information, e.g., utility function, decision rule, or heuristic, contained in local interactions. Repeated updating, interaction, and aggregation of local interactions can sufficiently generate the phenomenon over time from the "bottom up" (Nowak, 2004). Bearing this albeit brief conceptual unpacking of emergence (within the constraints of a conference proposal) in mind, we now turn our attention to methodologies for how one might seek understandings of emergent behavior of large-scale collective dynamics.

Unpacking Collective Dynamics

A complexity-grounded focus on collective dynamics, as argued earlier, requires that one undertake an ontological and, consequently, a methodological shift. Making this methodological shift, in turn, requires that one examine existing methodologies in CSCL research to see if and how they may be used to gain understandings of large-scale collective dynamics, and whether we need to integrate existing methods with others not currently used in CSCL research. Broadly speaking, existing methodological approaches in CSCL research fall into one or more of three categories: a) *experimental*, b) *descriptive*, and c) *design* (Suthers, 2006).

For the purposes of our argument, however, the three categories may be reduced to two. This is because the third category—design-based approach—at the compositional, methodological level (as opposed to the theoretical level) uses methods that are typically descriptive, though sometimes integrative (descriptive cum experimental) to understand and explain learning in CSCL groups. Design researchers offer rich accounts of an iterative exploration of the possibility space of designs; once promising or effective design features are identified, experimental methods may be used together with descriptive methods to document and explain the emergence of learning in collaborative settings (e.g., Barab & Squire, 2004). At the methodological level however, one could reasonably posit that the design approach, in the final analysis, typically resorts to descriptive or integrative (descriptive cum experimental) approaches to gain and explain phenomenological understandings (Bielaczyc & Collins, in press). For the purposes of this paper, therefore, it suffices that we discuss the experimental and descriptive approaches, examine their usefulness and limitations in studying small-scale collective dynamics, and evaluate if and how they may be used gain understandings of large-scale collective dynamics.

Experimental Approaches

Experimental (including quasi experimental) approaches are pervasively used in CSCL research (e.g., Suthers & Hundhausen, 2003; Kapur, 2006). They typically seek to establish causal or quasi-causal explanations of design or intervention effects versus control conditions. Reductive quantification of qualitative interactional data into categories followed by counting and aggregation, and then linear statistical modeling typify this approach. While this approach allows one to draw aggregated-level interpretations and conclusions about relationships between manipulated variables and their effects, it has been criticized for over-simplifying the complexity of interactional dynamics in CSCL groups. Still, it serves a valuable purpose as a method for making quantified causal or quasi-causal generalizations, especially as a complement to descriptive methods (Stahl et al., 2006). With our focus on emergent behavior of collectives, we also need to examine this approach with regard to its assumptions of linearity. The reason for this is startlingly simple: assumptions that work at the atomic or particle level may not work at the human or social level (Kauffman 1995); one must closely examine the assumption of linearity.

Linearity is usually conceived both as a mathematical operator as well as a functional relationship. A linear operator is essentially an additive operator. For example, traditional analytical methodologies such as linear differential equations and statistical modeling, regardless of their mathematical sophistication, are essentially linear operators. They work well for *closed*, *linear* systems (or approximations thereof) where the whole is equal to the *sum* of its parts, thus allowing for a reductive analysis; one can break a system into its components or parts, study the parts individually, and then *add* the parts together to form the whole. Applying the linear operator and its associated methodologies to the study of collective dynamics means that a collective is no more than a simple aggregate of the individuals. Clearly, critical information is lost when heterogeneous actors (parts) are aggregated or averaged into factors (Eidelson, 1997). However, large-scale collective dynamics is an emergent phenomenon; emergent properties, by definition, can not be obtained and analyzed no matter how one adds or aggregates the parts. Thus, a study of collective dynamics calls for methodologies which permit the modeling of *open*, *non-linear* systems where the whole is greater than the sum of its parts, systems that exhibit emergent behavior.

Linearity may also be conceived as a functional relationship—constant proportionality or a straight line. Thus conceptualized, methodologies resting on an assumption of linearity are restricted to studies of phenomena in which the effects are proportional to their causes; a restriction that precludes a wide range of real-world social phenomena, including large-scale collective dynamics. Linearity tends to treat small changes or perturbations as temporally transient without any long-term effects. However, collective dynamics is a phenomenon that exhibits non-linear effects. One can no longer assume that effects are proportional to their causes. In fact, small changes or perturbations can and usually do have large effects. Therefore, important non-linear relationships among variables may be missed entirely, or worse, be modeled linearly since that is what the method can handle. As Holland (1995) explained it, "Nonlinearities mean that our most useful tools for generalizing observations into theory—trend analysis, determination of equilibria, sample means, and so on—are badly blunted" (p. 5).

Taken together, traditional experimental approaches and its underlying assumption of linearity may fail to capture let alone model emergent and self-organizing behavior of complex phenomena such as large-scale collective dynamics. This is not to suggest that we abandon their use altogether; instead, understanding the limitations of applying linear reductive methods to study non-linear emergent phenomenon requires that one exercise caution and humility in what can be accomplished with using this approach for large-scale collective dynamics.

Descriptive Approaches

One of the fundamental orientations in CSCL is the social-participatory construction of meanings as an inter-subjective, in-situ phenomenon (Koschmann et al., 2005; Stahl et al., 2006). CSCL research has focused on this emergent meaning-making process through descriptive approaches designed to gain rich, data-driven, bottom-up understandings of the phenomenon as it unfolds. These methods include conversation analysis (Sacks, Schlegoff, & Jefferson, 1974), discourse analysis (Johnstone, 2002), narrative analysis (Hermann, 2003), and the likes. In CSCL research (e.g., Roschelle & Teasley, 1995; Koschmann et al., 2005) these methods have been used to uncover the emergence of learning in small groups. Because one could use these methods at multiple scales of a phenomena (e.g., conversation or discourse analysis at a micro level, and perhaps narrative analysis at a phenomenological level), when used together, they make for a more ecologically valid understanding of emergent phenomenon. Even so, limitations of descriptive methods for small-scale collective dynamics have been well-articulated. These include, in the main, an inability to establish causal explanations/generalizations of interventions and design decisions as well as an overemphasis on theory building as opposed to theory application (Stahl et al., 2006).

Other limitations are specific to their use in large-scale collective dynamics, which forms our main concern. Specifically, the sheer spatial-temporal scale of large-scale emergent phenomenon limits (not negate) the usefulness of in-depth, descriptive analysis, which, by definition, requires that one focus on a humanly-manageable portion of the spatial-temporal landscape: the entire space and time over which the phenomenon unfolds (Eidelson, 1997). For example, if one is examining authorial dynamics in Wikipedia using descriptive methods, then the choice of the method itself limits the scope of what one might choose for an in-depth study, perhaps one or a few articles. This, of course, would not pose any problems if the spatial-temporal landscape of Wikipedia (and large-scale collective dynamics in general) was uniform so that an understanding of a small part may be applied uniformly to the whole; unfortunately though, this is rarely the case.

From a temporal standpoint, self-organizing and emergent behavior often occurs through abrupt phase transitions that tend to happen in a narrow temporal band of a phenomenon's evolution (Kauffman, 1995). A descriptive analysis likely makes it difficult (though not impossible) to detect this in a consistent and reliable manner (Kruse & Stadler, 1993). Similarly, large-scale dynamics can display drastically different characteristics in different parts of their spatial-temporal landscape. For example, an in-depth description of a small part of that landscape, while informative and meaningful in its own right, does little if what one is really seeking is an understanding of the entire landscape. Large portions of the landscape may appear highly orderly, yet the seeds of chaotic and emergent behavior may be located in a small part. Again, a descriptive analysis may make it difficult (though not impossible) to detect this in a consistent and reliable manner (Kruse & Stadler, 1993). Still, an army of descriptive studies large-enough to be distributed over varied portions of the spatial-temporal landscape of the phenomenon may yet prove to be highly useful provided one could somehow coordinate and integrate these efforts into a meaningful whole.

Moving Forward

Realizing that each approach has something to offer small-scale collective dynamics, CSCL researchers have called for greater integration of these approaches moving forward (e.g., Suthers, 2006). We second this call. However, as we have argued, both the experimental and the descriptive approaches—alone or combined—have limitations as methodologies for understanding large-scale collective dynamics. We see combining the two to be a necessary step; yet, that alone is insufficient for examining large-scale collective dynamics. The inherent complexities of large-scale emergent phenomenon place limits even on an integrative approach (Holland, 1995).

In light of our focus on large-scale collective dynamics, this sets up an imperative for a methodology that builds on the experimental and descriptive methodologies and is also able to sufficiently generate the phenomenon from the "bottom up". Given the technological advances in computational simulation power, *Agent-Based Modeling* (ABM; we use ABM as short for both agent-based models and agent-based modeling) provides a methodological *complement* that is increasingly being used not only in the natural sciences (Jackson, 1996) but also in economics (e.g., Arthur, 1990), sociology (e.g., Watts & Strogatz, 1998), socio-cultural psychology (e.g., Axelrod, 1997), organizational science (e.g., Carley, 2002), etc., just to name a few. Grounded in complexity theory, agent-based modeling has already provided significant theoretical and empirical insights into the dynamics of large-scale social systems (Eidelson, 1997). In the following section, we briefly describe agent-based modeling and examine its methodological potential for understanding the dynamics of large-scale collectives.

Agent-based Modeling (ABM)

Over the past two decades, computational agent-based modeling has emerged as an important tool for social scientists seeking to understand complex social phenomenon (Eidelson, 1997). In fact, evidence from computational ABMs is increasingly being argued and endorsed as a third legitimate source of scientific evidence, a third way of doing science (Axelrod, 1997); the other two being direct observation and mathematical manipulation (Jackson, 1996). It is not surprising then that computational ABMs are being used pervasively in both the natural and the social sciences (e.g., the work cited earlier). It is only recently though that learning sciences' researchers have begun to entertain the possibility of using computational ABMs (see Jacobson & Wilensky, 2006; Goldstone, 2006). However, their potential and use in the learning sciences and CSCL research remains largely unexplored. Therefore, a brief description of computational ABMs is in order.

ABMs shift the focus from *factors* to *actors*; one no longer has to work with homogeneous actors aggregated into factors. Instead, one could maintain the *diversity* of agents in a population as *heterogeneous* actors, each with its own set of genetic and cultural traits as well as *simple rules* of behavior (Axelrod, 1997). ABMs leverage the cardinal principle of complexity stated earlier or what is also known as the principle of dynamical minimalism (Nowak, 2004): simple rules at the local level can sufficiently generate complex emergent behavior at the collective level (Bar-Yam, 2003). Requiring complex explanations for complex behavior is not an ontological necessity (Kapur et al., 2006); complex collective behavior may very well be explained via simple, minimal information, e.g., utility function, decision rule, or heuristic, contained in local interactions. Repeated updating and interaction of local interactions can sufficiently generate the phenomenon over time from the "*bottom up*" (Nowak, 2004). Heterogeneous actors interacting with each other over *space* and *time* give rise to emergent global structures and patterns and these, in turn, dialectically shape and constrain the subsequent interactions between agents. ABMs model these emergent behaviors from the "bottom up" by computationally simulating the interactions between individual actors and letting the system evolve *in silico* (Epstein and Axtell, 1996). So, rather than positing emergent structures *ab initio*, ABM seeks to generate and understand how these structures emerge in the first place and shape the very local behaviors they emerged from (for a review, see Vallacher & Nowak, 2005). Thus, one is no longer restricted to an analysis of static equilibria in social phenomena. With ABMs, one can take a pro-active, process-oriented analysis of collective dynamics.

As an example, consider the computational ABM of Social Impact Theory (Nowak, Szamrej, & Latané, 1990) that simulates how polarized clusters naturally emerge in public opinion. Building on previous theory and empirical evidence, an ABM for social influence operating via two interlocking, dialectical mechanisms is hypothesized: the group influences each person, and each person influences the group. The intensity of the dialectic is derived from a function of three variables: group size, personal persuasiveness, and personal position in physical (or social) space. During the course of evolution, i.e., the iterative application of the social influence function to each group-on-person and person-on-group interaction, the simulation evolves from an initial random distribution of opinions into emergent organizations of islands (clusters) of minority opinion in a sea of majority opinion; an emergent organization of opinions not unlike that in the real world.

In this example as well as others cited earlier, simple agents interacting with each other using simple rules could sufficiently generate the emergent complexities that are qualitatively similar to what we observe in social phenomenon. Thus, *verisimilitude*—the plausibility of behavior and patterns—lends explanatory power to computational ABMs (and indeed to other scientific methodologies as well; the notion of sufficiency of explanation is integral to scientific inquiry though standards for what counts as sufficient vary across the fields, e.g., in the learning sciences and CSCL research, a *p*-value of .05 or less is commonly accepted as sufficient to demonstrate a causal or correlational explanation). If simple mechanisms operating on minimal variables produce realistic phenomena in a simulated world, perhaps the same simple mechanisms operating on the same minimal variables produce real phenomena in the real world (Nowak, 2004). What seems life-like could perhaps be like life (Voiklis et al., 2006). Thus, one could hypothesize theoretically-sound, computational ABMs, perform computational experiments, and validate the results against theory and empirical data (Goldstone & Janssen, 2005). In so doing, computational ABMs push the very notion of what it means to *explain* a phenomenon, what Goldstone and Janssen (2005) refer to as a "proof-by-construction." Epstein and Axtell (1996) articulate this notion succinctly in their book *Growing Artificial Societies*. They argue,

> "What constitutes an explanation of an observed social phenomenon? Perhaps one day people will interpret the question, "Can you explain it?" as asking "Can you *grow* it?" Artificial society modeling allows us to "grow" social structures *in silico* demonstrating that certain sets of microspecifications are *sufficient to generate* the macrophenomena of interest. And that, after all, is a central aim. As social scientists, we are presented with "already emerged" collective phenomena, and we seek microrules that can generate them…But the ability to grow them—greatly facilitated by modern object-oriented programming—is what is new. Indeed, it holds out the prospect of a new, *generative*, kind of social science." (Epstein & Axtell, 1996, p. 20)

While this may seem somewhat an over-enthusiastic endorsement, the ability of computational ABMs to model or "grow" emergent social phenomenon from the "bottom up" does provide an ontological coherence between the method and its object of inquiry. Epistemological and, consequently, methodological debates within the scientific discourse about the nature of knowledge and knowing from computational ABM experiments are also increasingly leaning in favor of computational ABM (PNAS, 2002). Still, these debates suggest that computational ABM is not without its own set of limitations. For example, while verisimilitude proves essential to the theory-building efforts of those trying to understand large-scale collective dynamics, clearly, an over-reliance on verisimilitude may strain one's evidentiary standards (Voiklis et al., 2006). Because of this, there is a great need for phenomenological validation of results derived from computational ABM (Goldstone & Janssen, 2005).

How might one achieve such phenomenological validation? Cioffi-Revilla (2002) suggests concrete steps for robust sensitivity and invariance analyses of computational ABMs to ensure that the simulated results are not merely "synthetic outcomes." Minimally, this may include examining the sensitivity and invariance of simulated results to *system size* (number of interacting agents), *agent geometry* (the structure of the spatial landscape on which agents interact, e.g., lattices), and *network topology*. Additionally, simulated results also need to be calibrated with respect to real-world phenomenon. Phenomenological *time calibration* would help ascertain the correspondence between notional time (the number of iterations in the simulation) and referent time (hours, days, months, years, etc.). Phenomenological *magnitude calibration* would help ensure correspondence between simulated and real phenomenon in terms of the magnitude or size or intensity of emergent behaviors. Phenomenological *distributional calibration* would help ensure that distributions (often power laws) that emerge in simulated phenomenon parametrically correspond with those in the real phenomenon.

As the field advances, this list will grow, as well it should. It is hoped that a persistent conversation between advocates and skeptics will potentially generate new ideas for phenomenological validation of computation ABMs. Over time, standards and metrics for what makes a *sufficient* explanation may emerge within this conversation. From the conversation thus far though, one thing is crystal clear: computational ABM alone too is insufficient; it cannot be done in isolation. One needs an integrative approach that builds on existing methodologies. For example, existing theoretical and empirical phenomenological understandings (gained through methods experimental, descriptive, or both) could be used to articulate critical variables and interactional rules between individuals agents in a collective. This, in turn, could be used to design agents and their interactional rules, which the computational ABMs could then simulate. Upon phenomenological validation, insights derived from the simulated collective behavior could in turn inform our theory building efforts. Importantly, a repeated, iterative application of this process cycle is most essential and forms the thrust of our methodological position for the study of computer-supported, large-scale collective dynamics. It is through such an iterative process of *building from* and *validating with* phenomenological theory and data—an *iterative* "*phenomenological-ABM-theory building*" cycle—that we seek a better understanding of large-scale collective dynamics: ABMs are hypothesized from theory and empirical data. Computational experiments using ABMs, in turn, provide new insights, explain empirical data, and inform theory building. This dialectic forms the epistemological and methodological core of our proposal.

Implications for a Research Agenda

To reiterate, our proposal for an overarching question driving the research agenda for computer-supported large-scale collective dynamics is: *How and under what conditions does learning—structures, participation patterns and culture, organizations, knowledge, values, norms, etc.—emerge from the interactions between individuals in computer-supported, large-scale collectives, and how do these emergents shape and constrain subsequent interactions between and participation of individuals in these collectives?* The research question, at this stage, remains necessarily broad. Still, it has been identified as a substantive and critical area for further inquiry not only by social scientists in general (e.g., Epstein & Axtell, 1996; PNAS, 2002) but also by cognitive scientists (e.g., Goldstone & Janssen, 2005) as well as learning scientists and CSCL researchers (e.g., Suthers, 2006). In CSCL research, the proposed research agenda might also help validate a fundamental hypothesis underpinning small-scale collective dynamics: small-groups form the critical organization that mediate between the individual and the larger community (Stahl et al., 2006). If this is so, this can be tested using the phenomenological-ABM inquiry cycle. For example, if one starts to see small group organizations emerging within the larger collective as the system evolves, then that may be one source of evidence—a generative, bottom-up, proof-by-construction—for the hypothesis.

We also argue, however, that any *comprehensive* research agenda for understanding large-scale collective dynamics will have to be multi-modal—offline and online. Why this is the case may not immediately obvious. Hence, it merits an explanation. One of the reasons for studying large-scale collective behavior in online societies and communities such as 2nd Life, Wikipedia, communities of practice, etc. is that a lot of people are increasingly participating in them (Jenkins, 2006). The emergence of an online community is contingent on such participation by real people in real networks across the world, i.e., as more people participate, they collectively create emergent structures online. In turn, this makes even more people participate setting up an *increasing returns* (Arthur, 1990) feedback loop. Clearly, emergent collective behavior in these environments not only shapes but is shaped by their spread in the real (as opposed to virtual) large-scale network, e.g., a population or a system. Thus, a study of collective behavior in large-scale online environments is incomplete without a study of how participation in such environments spreads in a real population or a system, i.e., the real and the virtual become a co-emerging, co-evolutionary phenomenon, and we argue that they must be examined and understood as such. If this is a plausible proposition, then a co-evolutionary research question becomes: *How does emergent behavior of computer-supported, large-scale collectives co-evolve with their diffusion or spread in a real (as opposed to virtual) large-scale network, e.g., a population?*

Finally, driving this research agenda is also an opportunity for data collection that is somewhat unique to computer-supported large-scale collectives. Many of these collectives have fairly complete records of their evolution automatically archived. Better still, these archival data are often freely available or one can design web-crawlers to seek required data from these archives. This clearly presents a unique opportunity to further the research agenda in this area (Goldstone & Janssen, 2005), which is precisely what the proposed research agenda aims to achieve.

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Sensitivities to Early Exchange in Synchronous Computer-supported Collaborative Learning (CSCL) Groups

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Abstract: This study reports the impact of high sensitivity to early exchange in 11th-grade, CSCL triads solving well- and ill-structured problems in Newtonian Kinematics. Analysis of the evolution of participation inequity (PI) in group discussions suggested that participation levels tended to get locked-in relatively early on in the discussion. Similarly, high (low) quality member contributions made earlier in a discussion did more good (harm) than those made later on. Both PI and differential impact of member contributions suggest a high sensitivity to early exchange; both significantly predicting the eventual group performance, as measured by solution quality. Consequently, eventual group performance could be predicted based on what happened in the first 30-40% of a discussion. In addition to theoretical and methodological implications, implications for scaffolding CSCL groups are drawn.

Introduction

The role of collaborative interaction and participation is central to the socio-constructivist perspective on learning; a perspective that undergirds much of computer-supported collaborative learning (CSCL) research (Scardamalia & Bereiter, 2003; Stahl, 2005). Naturally, a major concern in CSCL research is why some groups are more successful than others. Historically, researchers have sought to address this concern by focusing on the effects of pre-existing group characteristics and member traits (e.g., group size, group ability, prior knowledge, heterogeneity, status, personality composition, learning styles, etc.) on group performance (e.g., Webster & Driskell, 1983; McAuliffe, 1991; Webb & Kenderski, 1984; Cohen, 1982; Webb, 1984; Sharan & Shachar, 1988; Lam, 1997).

Lately, though, there has been a push towards unpacking group processes, in particular the complexities of interactional dynamics and how it influences group performance; the nature of member interactions and participatory patterns forming key objects of inquiry. In fact, a realization of the inherent complexity of interactional dynamics is giving way to a more *temporal* and *emergent* view of how groups function and perform (Stahl, 2005; Arrow, McGrath, & Berdahl, 2000). This presents a unique challenge to traditional analytical measures and methods for analyzing group processes (Barab, Hay, Yamagata-Lynch, 2001); existing methods continue to take cumulative accounts of member interactions (e.g., categorization of interactional content, rating of discussion quality, member perceptions, and so on) and relate them to group performance. While these accounts are useful, they fail to fully utilize the temporal, evolutionary information embedded in the data (Kapur, Voiklis, Kinzer, & Black, 2006). Therein lies the need for the research reported in this paper.

We start with a brief review of how interaction and participation have been studied in CSCL research. A substantial amount of literature attempts to understand group processes using qualitative analytical methods, which provide insightful and meaningful micro-genetic accounts. For the present purposes, however, our analysis is limited to quantitative approaches, typically involving quantitative content analysis (QCA) (Chi, 1997) of interactional data; the use of QCA or what is commonly also referred to as "coding and counting" being pervasive in examining the nature of interaction and participation in CSCL research (Rourke & Anderson, 2004).

Nature of Interactions and Participation in CSCL Groups

Nature of Interactions

Because learners interact with and influence each other in the process of problem solving, these interactions form the most important units of analyses for research; problem-solving interactions have been used extensively in investigating productivity conditions of small, collaborative groups (e.g., Scardamalia, 1989, 1992; Scardamalia &

Bereiter, 1993; Bereiter, Scardamalia, Cassells, & Hewitt, 1997; Jonassen & Kwon, 2001; Barron, 2003; Cohen et al., 2002; Schellens, Van Keer, & Valcke, 2004; Zumbach, Schonemann, & Reimann, 2005; Spada, Meier, Rummel, & Hauser, 2005; Lee, Chan, & van Aalst, 2006; Kapur, 2006).

A common analytical thread runs through these investigations: they typically employ one or more coding/rating schemes, which when applied to the interaction data result in a cumulative frequency or relative frequency distribution of interactions across the categories of the coding/rating scheme (e.g., depth of explanations, functional content of interactions, misconceptions, quality, correctness, etc.). These distributions essentially tally the amount, proportion, and type of interactions vis-à-vis the interactional coding/rating scheme (Suthers, 2006). Significant links are then sought between quantitatively-coded interactional data and outcomes, such as quality of group performance and group-to-individual transfer (see Rourke and Anderson (2004) for a discussion on the validity of QCA).

Notwithstanding the empirically-supported significant links between the nature of interactional activity and group performance, interpreting findings from interactional coding/rating schemes is limited by the very nature of the information tapped by these measures. For example, what does it mean if a group discussion has a high proportion of, say, problem definition type of interactional activity? Clearly, answering this question is problematic when one considers two contrasting possibilities, both corresponding to the same proportion of problem definition type of interactional activity in a group. It could be that the group's attempt at defining the problem was spread throughout the discussion, or perhaps all such activity was clustered together in a coherent phase during the discussion. Furthermore, problem definition contributions that are temporally far apart in a discussion carry the same weight in the cumulative count or proportion; one that comes later in a discussion is given the same weight as one that comes earlier. Such an analysis, while informative, does not take the temporality of interactions into account, i.e., the time order of interactions in the problem-solving process. In light of the complexities of interactional dynamics in CSCL, it is surprising how frequently this assumption of *temporal homogeneity* is made without justification or validation. This study was designed to examine this assumption.

Participation

With regard to participatory patterns of group members, previous research has attempted to link individual participation with group performance as well as subsequent group-to-individual transfer. The study of participation in collaborative settings has primarily been studied at the individual level. Typically, research has focused on questions like - how an individual's participation rate in a group affects his/her achievement gains, or, how being part of a group with intensive interactional activity affects an individual's achievement gains, and other variants of the same (Cohen, 1994; Schellens, Van Keer, Valcke, & De Wever, 2005). Hence, they may suffer from ecological and atomistic fallacies in moving back and forth between the interpretation of findings at the individual and group levels.

An obvious work-around is to consider participation inequity as a group-level construct, as operationalized in the study described herein. After all, high participation inequity implies that group performance is primarily influenced by one or two dominant members. This leaves little opportunity for multiple perspectives, strategies, and solutions to be shared and discussed. Yet, the effect of participation inequity (as a group-level construct) on group performance remains relatively unexplored (e.g., Kapur & Kinzer, 2005).

In addition to focusing primarily on the effects of an individual's participation, previous research on participation in CSCL also makes a temporal homogeneity assumption: participation rates are cumulatively summed over the entire discussion (e.g., Schellens et al., 2005; Kapur & Kinzer, in press). By cumulative summing, however, one does not know whether member participation was greater earlier in the discussion or later; whether participation inequities evolve slowly or quickly. In other words, two things are ignored or assumed to be negligible in non-weighted summing of participation instances: temporal variation in a given member's participation over the course of a discussion, and consequently, participation inequity at the group level. Once again, there is an assumption of *temporal homogeneity*, this time for group participation inequity. However, this assumption is made without justification or validation.

Purpose

The purpose of this study was to test the temporal homogeneity assumption within the short-term, problem-solving efforts of synchronous, CSCL groups. We started by examining the temporal homogeneity of participatory patterns, specifically the evolution of participation inequity in CSCL groups. Our analysis revealed that the assumption of temporal homogeneity did not hold. Group performance was highly sensitive to participation inequities in the early exchange between group members; inequities during this sensitive period of early exchange seemed to get "locked in" for the rest of the discussion. In turn, this led us to examine the assumption of temporal homogeneity in terms of the impact that the quality of member interactions had on a group's discussion.

Method

Research Context and Data Collection

Participants included sixty 11^{th}-grade students (46 male, 14 female; 16-17 years old) from the science stream of a co-educational, English-medium high school in Ghaziabad, India. They were randomized into 20 triads and instructed to solve either a well-structured (WS) or an ill-structured (IS) authentic car accident scenario that required the application of concepts in Newtonian kinematics. The study was carried out as part of their regular classroom activity, where group members communicated with one another only through synchronous, text-only chat. The 20 automatically-archived transcripts, one for each group, contained the group discussions as well as their solutions, and formed the data used in our analyses.

Procedure

A well- and an ill-structured problem scenario were developed consistent with Jonassen's design theory typology for problems (2000). Both problem scenarios dealt with a car accident scenario that required participants to apply principles of Newtonian Kinematics and Laws of Friction to solve them (see Appendix). Content validation of the two problem scenarios was achieved with the help of two physics teachers from the school with experience in teaching those subjects at the senior secondary levels. The teachers also assessed the time students needed to solve the problems. Feedback from the teachers resulted in minor modifications to the problem scenarios, which were them deemed to be consistent with the school's curriculum.

Problem classification validation was then undertaken by having the top three tenth-grade science students and the two teachers classify the two problems as being either well- or ill-structured. All students' and teachers' classifications were unanimously consistent with those of the researchers. The same three students were also asked to solve the problems to confirm that two hours would be sufficient time for the task. All of them completed the problems and submitted their work in about one hour. However, for group work, we decided to give each group two hours to allow sufficient time for group interaction and discussion; naturally, we didn't want a lack of time to be a confounding factor. Ultimately, all groups completed the problem in the allotted time.

The study was carried out in the school's computer laboratory where participants normally engage in a substantial amount of curricular problem solving activities. The online synchronous collaborative environment was a java-based, text-only chat application running on the Internet. Despite these participants being technologically savvy in using online chat, they were familiarized in the use of the synchronous text-only chat application prior to the study. Group members could only interact within their group. Each group's discussion and solution were automatically archived as a text file to be used for analysis. A seating arrangement ensured that participants of a given group were not proximally located so that the only means of communication between group members was synchronous, text-only chat. To mitigate status effects, we ensured that participants were not cognizant of their group members' identities; the chat environment was configured so that each participant was identifiable only by an alpha-numeric code. Cross-checking the transcripts of their interactions revealed that participants followed the instruction not to use their names and instead used the codes when referring to each other. No help regarding the problem-solving task was given to any participant or group during the study. Furthermore, no external member roles or division of labor were suggested to any of the groups. The procedures described above were identical for both WS and IS groups. The time stamp in the chat environment indicated that all groups made full use of the allotted time of two hours and solved their respective problems.

Results

Evolution of Participation Inequity (PI)

In this study, PI was conceived as a group-level construct and operationalized as the standard deviation (SD) of the three member participation proportions (number of utterances by a member as a proportion of total utterances) within each group. A low SD implies closely clustered participation ratios within a group, i.e., a participation pattern that is more or less uniform and equitable. For example, the *SD* of the participation proportions

.4, .3, and .3 equals .06. Thus, a low *SD* implies closely clustered participation proportions within a group—an *equitable* participation pattern. On the other hand, a high SD implies a discussion that is dominated by one or two members within the group, i.e., an inequity in the participation of members in the group. For example, the *SD* of participation proportions .8, .15, and .05 equals .41. Thus, a high *SD* implied a discussion dominated by one or two members within the group—an *inequitable* participation pattern. Next, PIs after each utterance in a discussion were calculated, giving the level of PI in the discussion up to any given utterance. Plotting these values over time (defined notionally with utterances as *ticks* on the evolutionary clock) reflected the temporal development of PI for the 20 groups. Figure 1 shows the typical trajectories for WS and IS groups.

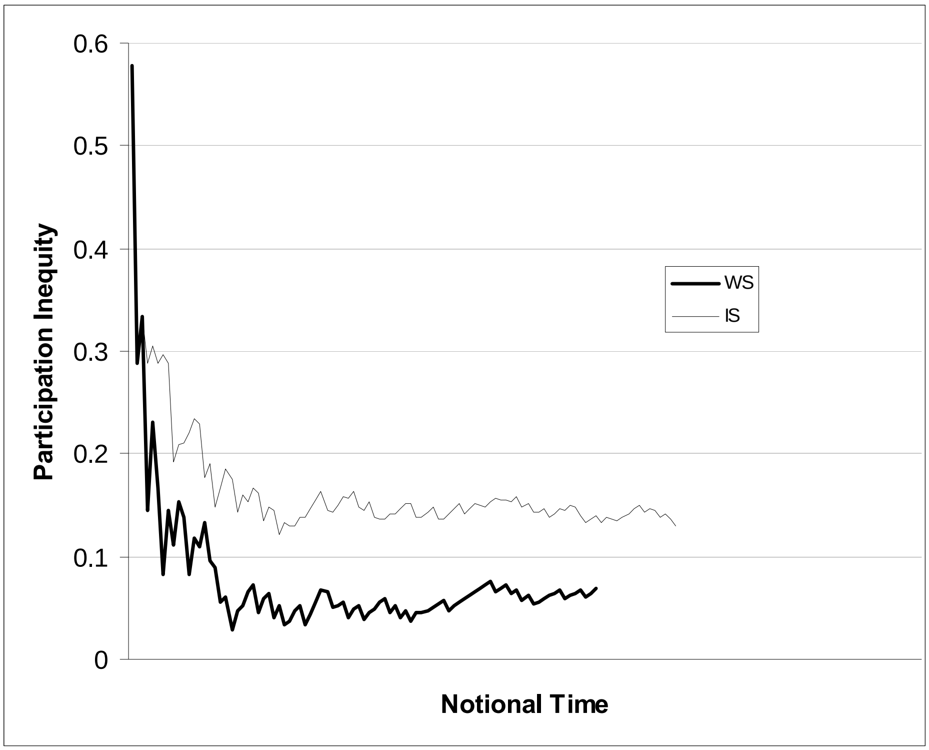

Figure 1. Evolution of participation inequities across problem types

What was surprising was how sensitive the evolution of these trajectories was to the early exchange between group members in both WS and IS groups. This can be seen in the sharp fluctuations in the trajectories in Figure 1 before they quickly settled into an inequity plateau. The main difference between WS and IS groups seemed to be that the former typically settled into a lower plateau (i.e., lower PI; higher equity) whereas the latter into a higher plateau (i.e., higher PI; lower equity). This difference between WS and IS groups is interesting in and of itself and we unpack it in greater detail elsewhere (Kapur & Kinzer, in press). For the present purposes, however, we focus on the patterns across the groups, treating problem type as a control variable. This would allow us to focus on what is significant across the WS and IS groups, i.e., PI evolution was not a gradual process but one that was highly sensitive to early exchange. Critically, inequities during this sensitive period of early exchange seemed to get "locked in" for the rest of the discussion, i.e., once settled into an inequity plateau early in the discussion groups were, on average, unlikely to escape it.

Given the above finding, the logical question becomes: how does the early lock-in of PI influence group performance? To answer this question, group performance was operationalized as the quality of group solution, independently rated by two doctoral students on a 9-point rating scale (Table 1) with an inter-rater reliability (*Krippendorff's alpha*) of .95. An analysis of variance (ANOVA) (Table 2) showed that, controlling for problem type, PI was a significant predictor of eventual group performance (F = 8.484, p = .010); High PI resulting in low group performance, on average. Levene's test for equality of error variance was not significant (F = .782, p = .388).

Table 1. *Rubric for coding quality of group solution*

Quality	Description
0	Solution is weakly supported, if at all
1	Solution supported in a limited way relying either on a purely quantitative or a qualitative argument with little, if any, discussion and justification of the assumptions made
2	Solution is only partially supported by a mix of both qualitative and quantitative arguments; assumptions made are not mentioned, adequately discussed, or justified to support the decision
3	Solution synthesizes both qualitative and quantitative arguments; assumptions made are not adequately discussed and justified to support the decision
4	Solution synthesizes both qualitative and quantitative arguments; assumptions made are adequately discussed and justified to support the decision

Note: Mid-point scores of .5, 1.5, 2.5, and 3.5 were assigned when the quality of solution was assessed to be between the major units 0, 1, 2, 3, and 4, making the scale essentially a 9-point scale.

Table 2. *Model summary for predicting group performance from PI*

Source	***SS***	***df***	***MS***	***F***	***p***	**Partial Eta Squared**	**Power**[a]
Intercept	25.690	1	25.690	31.743	.000	.651	1.000
Participation Inequity	6.867	1	6.867	8.484	.010	.333	.784
Problem Type	.434	1	.434	.537	.474	.031	.106
Error	13.758	17	.809				
Total	81.250	20					

[a] Computed using alpha = .05
[b] R Squared = .516 (Adjusted R Squared = .459)

These findings support the view that early lock-in of PI is significant, for it suggests that the impact of early exchange on group performance is much greater than what comes later. The seeds of eventual group performance seem to be sown fairly early in a group's discussion. Because a lock-in of participation levels also implies a lock-in to the dominant members' proposals or contributions, it meant that one could no longer assume member contributions made a temporally homogenous impact on group performance. It is this analysis that we turn our attention to next.

Evolution of Differential Impact of Member Contributions

Quantitative content analysis (QCA; Chi, 1997) was used to segment utterances into one or more interaction units. The interaction unit of analysis was semantically defined as the impact(s) that an utterance had on the group discussion (Bransford & Nitsch, 1978). Adopting Kapur et al.'s methodology (2006), an impact value of 1, -1, or 0 was assigned to each interaction unit depending upon whether it moved the group discussion toward (impact = 1) or away (impact = -1) from the goal of the activity—a solution state of the given problem, or maintained the status quo (impact = 0). Therefore, each discussion was reduced to a temporal string of 1s, -1s, and 0s, i.e., a non-random walk (Ross, 1996). Two trained doctoral students independently coded the interactions with an inter-rater reliability (*Krippendorff's alpha)* of .85. This impact coding is illustrated through a brief micro-analytical analysis of the following excerpt containing an exchange between group members S1 and S2.

S1 *> are we going to apply frictional retardation for the reaction time also?*	-1
S2 *> no, because reaction time is the time between watching the boy and applying the brakes so in this time car must be accelerating*	1, 1
S1 *> but I think we must not forget that the car is moving on the same road on which the incident occurs and the road is providing the retardation*	-1, -1
S2 *> but maximum speed is at the instant when he applied the brake*	1
S1 *> but earlier you said that the car will accelerate after perceiving the boy*	-1
S2 *> I said so because his foot must be on accelerator during reaction time*	1
S1 *> Now I understand… please proceed to write your answer*	1, 1

Recall that the problem involved a car-accident scenario. In this excerpt, S1 and S2 are trying to decide whether or not reaction time of the driver of the car that was involved in the accident should factor into their calculations. The excerpt starts with S1 asking a question about applying frictional retardation during reaction time of the driver. Being a misconception, it was rated as having a negative impact (-1) on the group's progress towards solving the problem—a collective divergence from the goal of solving the problem. S2 evaluates S1's question and says '*no*,' attempting to correct the misconception. Hence, its positive (+1) impact rating – a local divergence between S1 and S2 but a collective convergence towards the goal. In the same utterance, S2 elaborates why frictional retardation should not to be applied, further positively impacting the group's progress – continued local divergence but increasing collective convergence towards the goal. The argument continues with S1 persisting with the misconception (assigned negative impacts) until S2 is able to convince S1 otherwise (assigned positive impacts), thereby converging on a correct understanding of this aspect (dealing with friction during reaction time) of the problem given to them – both local as well as collective convergence toward the goal is achieved. Note that had S2 wrongly evaluated and agreed to S1's misconception, S2's impact ratings would have been negative, which, without any further correction, would have led the group to diverge from a correct understanding of the aspect of the problem being considered.

As applied, however, the impact coding not only takes into account local convergence but also convergence of the group as a whole toward solving the problem; impact ratings are meaningful only in relation to preceding utterances (Bransford & Nitsch, 1978) and take into account the sequence and temporality of collaborative interactions (Kapur et al., 2006). Other examples of highly convergent discussion episodes would include agreement with and positive evaluation and development of correct understandings of the problem, solution proposals, and problem solving strategies.

More formally, let n_1, n_{-1}, and n_0 denote the number of interaction units assigned the impact values 1, -1, and 0 respectively up to a certain utterance in a discussion. Then, up to that utterance, the mean impact (henceforth referred to as convergence) in terms of moving the group towards or away from the goal is given by the mean distance of the Markov walk, $C = \dfrac{n_1 - n_{-1}}{n_1 + n_{-1}}$ ($-1 < C < 1$). Convergence values were calculated after each utterance, resulting in a notional time series representing the evolution of member contributions' impact on the group discussion. Plotting the convergence value on the vertical axis and time (defined notionally with utterances as *ticks* on the evolutionary clock) on the horizontal axis, one gets a representation (also called a fitness curve) of the problem-solving process as it evolves in time. Figures 2 and 3 present the four major types of fitness curves that emerged from the discussion of the 20 problem-solving groups in our study. These four fitness curves contrast the high- with the low-performing groups across WS and IS groups.

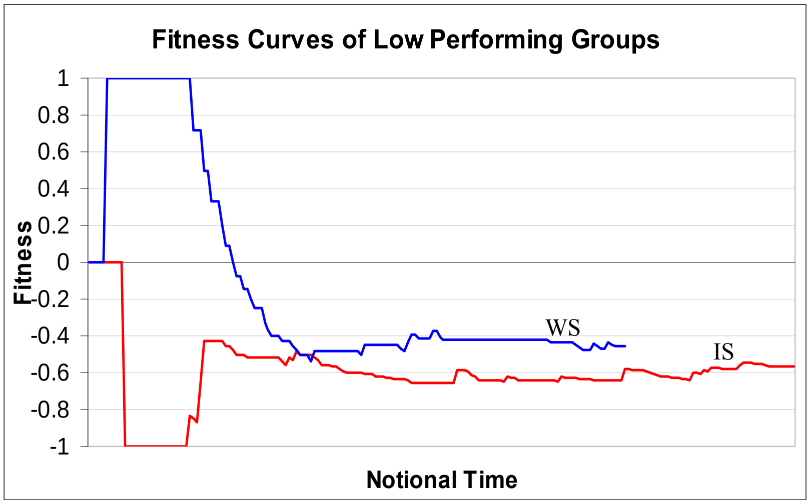

Figure 2. Fitness curves of low-performing groups across problem types

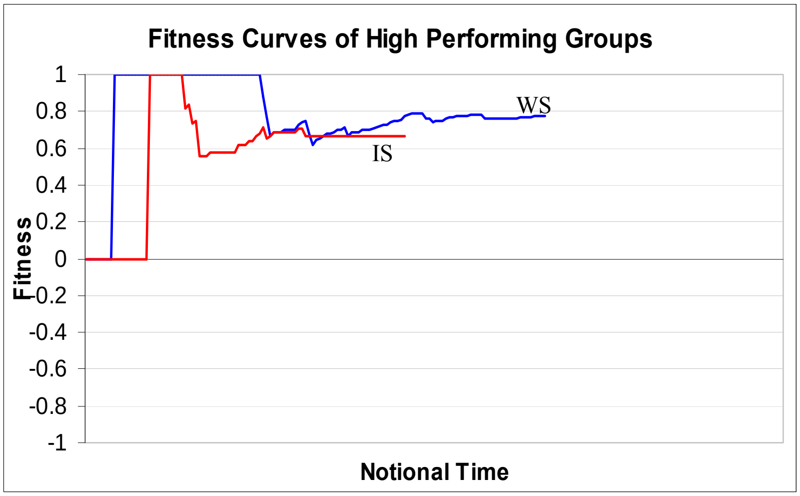

Figure 3. Fitness curves of high-performing groups across problem types

Interpreting Fitness Curves

It is easy to see that the convergence value always lies between -1 and 1. The closer the value is to 1, the higher the convergence, and the closer the group is to reaching a solution. The end-point of the fitness curve represents the final fitness level or convergence of the entire discussion. From this, the extent to which a group was successful in solving the problem can be deduced. Furthermore, one might imagine that an ideal fitness curve is one that has all the moves or steps in the positive direction, i.e., a horizontal straight line with fitness equaling 1. However, the data suggests that, in reality, some level of divergence of ideas may in fact be a good thing (Schultz-Hardt et al., 2002; Kapur, 2006), as can be seen in the fitness curves of both the high-performing groups.

The shape of the fitness curve, therefore, is also informative about the paths respective groups take toward problem solution. For example, in Figure 2, both the low-performing groups converged at approximately the same (negative) fitness levels, but their paths leading up to their final levels were quite different. The WS group showed a sharp fall after initially moving in the correct direction (indicated by high fitness initially). The IS group, on the other hand, tried to recover from an initial drop in fitness but was unsuccessful, ending up at approximately the same fitness level as the well-structured group. Further, comparing the high-performing groups (Figure 3) with the low-performing groups (Figure 2), one can see that the discussions of high-performing groups had fewer utterances, regardless of problem type. Finally, all fitness curves seemed to settle into a *fitness plateau* fairly quickly. Again, as with PI, once the fitness was "locked in", groups found it increasingly difficult to escape it.

What is most interesting is that this temporal, albeit descriptive, examination of fitness curves provides a view of paths to a solution that are lost in analysis systems that assume temporal homogeneity and consider only a given point in the solution process, thus assuming that similar behaviors or states at a given point are arrived at in similar ways. As different paths can lead to similar results, unidimensional analyses that cumulatively consider only single points in time (often only the solution state) are not consistent with what this study's data suggest about CSCL processes.

Most important is a mathematical property of convergence. Being a ratio, convergence is more sensitive to initial contributions, both positive and negative, than those made later in the process. This can be easily seen because with each positive (or negative) contribution, the ratio's numerator is increased (or decreased) by 1. However, the denominator in the ratio always increases, regardless of the contribution being positive or negative. Therefore, when a positive (negative) contribution comes earlier in the discussion, its impact on convergence is greater because a unit increment (decrement) in the numerator is accompanied by a denominator that is smaller earlier than later. Said another way, this conceptualization of convergence allows us to test the *differential temporal impact* hypothesis: *"good" contributions made earlier in a group discussion, on average, do more good than if they were made later. Similarly, "bad" ones, on average, do more harm if they come earlier than later in the discussion*. To test this hypothesis, the relationship between convergence and group performance was explored by running a temporal simulation on the data set.

Testing the Differential Temporal Impact Hypothesis

The purpose of the simulation was to determine if the level of convergence in group discussion provided an indication of the eventual group performance. Recall that group performance was operationalized as the quality of group solution. The discussions of all 20 groups were each segmented into 10 equal parts. For example, a discussion comprising 300 utterances was divided into 10 parts of 30 utterances each; a discussion comprising 150 utterances was divided into 10 parts of 15 utterances each, and so on. At each tenth, the convergence value up to that point was calculated. This resulted in 10 sets of 20 convergence values; the first set corresponding to convergence in the discussion after 10% of the discussion was over, the second after 20% of the discussion was over, and so on until the tenth set, which corresponded to the final convergence value of the discussion, i.e., after 100% of the discussion had occurred. A simulation was then carried out by regressing group performance on convergence values at each tenth of the discussion (hence, a temporal simulation), controlling for problem type (WS or IS) each time. The *p*-value corresponding to the statistical significance of the predictive power of convergence at each tenth of the discussion on eventual group performance was plotted on the vertical axis (see Figure 4). C1 through C10 denote the 10 equally-spaced instances in each discussion at which the convergence values were calculated. The simulation suggested that, on average, at some point after 30% but before 40% of the discussion is over (i.e., between C3 and C4 in Figure 4), the convergence value is able to predict eventual group performance at the .05 level of significance or better. This shows that convergence is a powerful measure that is able to model the impact that early contributions have on eventual group performance.

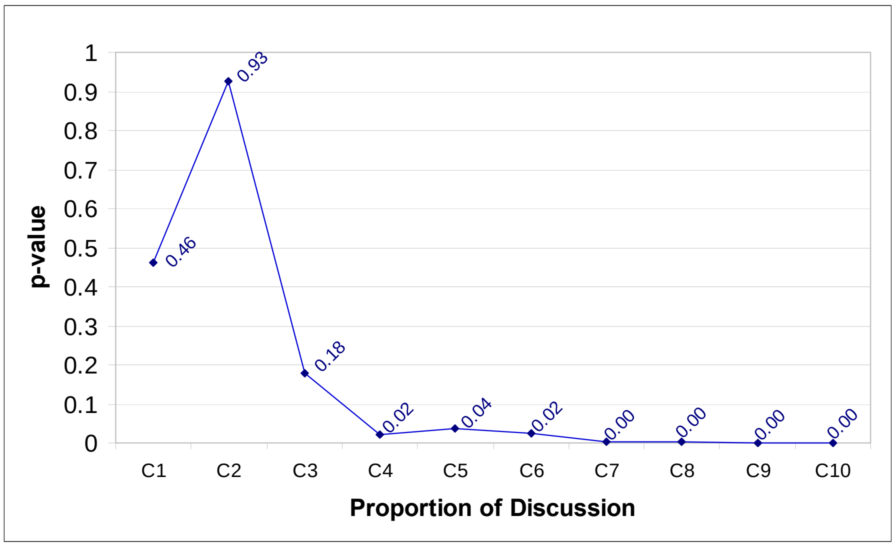

Figure 4. Simulation of the significance of convergence in predicting group performance

More importantly, this shows that the differential temporal impact hypothesis holds up to empirical scrutiny; eventual group performance is highly sensitive to early exchange, not just in terms of PI but also differential impact of member contributions. It is important to note that while both PI and convergence independently predicted group performance, they were also significantly negatively correlated (r = -.538, p = .014). Notwithstanding, when included in an ANOVA together (see Table 3), both remained significant predictors of group performance (F = 7.144, p = .017 & F = 16.789, p = .001 respectively), controlling for problem type.

Table 3. *Model summary for predicting group performance from PI and Convergence*

Source	***SS***	***df***	***MS***	***F***	***p***	**Partial η^2**	**Power[a]**
Intercept	.218	1	.218	.520	.481	.032	.104
Participation Inequity	2.998	1	2.998	7.144	.017	.309	.709
Convergence	7.045	1	7.045	16.789	.001	.512	.970
Problem Type	.156	1	.156	.371	.551	.023	.088
Error	6.714	16	.420				
Total	81.250	20					

[a] Computed using alpha = .05; [b] R Squared = .764 (Adjusted R Squared = .720)

Discussion

This study revealed novel insights into the problem-solving process of CSCL groups. Its most important implications stem from the finding that the sensitivity to early exchange tends to lock-in participation levels, which eventually determined how successful a group was in solving the given problem. This finding becomes even more significant because participation in high-performing groups is consistently a strong predictor of subsequent individual learning gains (e.g., see Barron, 2003; Cohen et al., 2002; Schellens et al., 2005). Furthermore, because a lock-in of participation levels also implies a lock-in to dominant members' proposals, those members' high (low) quality contributions have a greater positive (negative) impact on the eventual outcome when they come earlier than later in a discussion. Our findings indicate that eventual group performance could be predicted based on what happens in the first 30-40% of a discussion. This is not to say that contributions made later in a discussion are not important. Instead, once a discussion gets locked in, it gathers inertia, and it becomes increasingly difficult for individuals' subsequent proposals to make an impact proportional to their quality.

Implications for Scaffolding

If, as this study suggests, group performance is highly sensitive to the early exchange in the discussion, then this insight bears important implications for scaffolding synchronous, small-group, CSCL discussions to achieve optimal outcomes. For example, if one's interest is primarily in maximizing group performance, the insight suggests a need for scaffolding early in the discussion, since the impact of early interactional activity on eventual group performance seems to be greater. Scaffolding earlier parts of a group discussion may increase its likelihood of settling into lower inequity and higher fitness plateaus; better group performance is predicated by low and high inequity and fitness plateaus, respectively. This is also consistent with the notion of fading: having scaffolded the early exchange, the scaffolds can be faded. For example, instead of scaffolding the entire process of problem solving using process scaffolds, it may only be necessary to scaffold how a group analyzes and frames the problem, as these often occur early in problem-solving discussions. Such an approach stands somewhat in contrast with the common practice of blanket scaffolding of the CSCL processes (e.g., through the use of collaborative scripts). The above are testable hypotheses that emerge from this study and we invite the field to test and extend this line of inquiry.

Implications for Conceptualizing CSCL Groups

Interestingly, sensitivity to early exchange exhibited by CSCL groups in our study seems analogous to sensitivity to initial conditions exhibited by many complex adaptive systems (Bar-Yam, 2003; Arrow et al., 2000)); the idea being that small changes initially can lead to vastly different outcomes over time, which is what we found in our study. Furthermore, the locking-in mechanism is analogous to *attractors* in the phase space of complex systems (Bar-Yam, 2003). Phase space refers to the maximal set of states a complex system can possibly find itself in as it evolves. Evidently, a group discussion has an infinite phase space, yet the nature of early exchange can potentially determine whether it organizes into higher or lower inequity and fitness attractors. Thus, an important theoretical and methodological implication from this finding is that CSCL research needs to pay particular attention to the temporal aspects of interactional dynamics. As this study demonstrates, studying the evolution of interactional patterns can be insightful, presenting counterintuitive departures from assumptions of linearity in, and temporal homogeneity of, the problem solving process (Kapur et al., 2006).

Conclusion

This study was designed to examine the temporal homogeneity assumption that is often made in the study of CSCL groups. In particular, it demonstrated the inadequacy of assuming temporal homogeneity of participation patterns as well as the impact of member contributions. Our analysis revealed that group performance was highly sensitive to early interactional activity; both participation inequity and differential impact of member contributions significantly predicting the eventual group performance. All in all, this study offers preliminary yet compelling insights into the nature and dynamics of problem-solving CSCL groups. We fully acknowledge that our findings are technically bound by the context within which this study was conducted. Additionally, there are other factors such as prior knowledge, writing ability, gender, group composition, learning styles and dispositions, the nature of the task itself, affordances of the online chat environment, etc. that could just as well have influenced our findings. Still, in taking these first, essential steps toward understanding of how temporality affects CSCL group functions and performance, we call for further efforts within this line of inquiry.

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Animated science education: Possible pitfalls of computer supported collaborative learning

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Misconceptions – This notion is one of the grand themes of educational research in general and science education in particular. Students' misconceptions of various scientific principles are recurrent topics in numerous studies, in for instance physics (D. E. Brown, 1992; Jones, 1991), biology (C. R. Brown, 1990; Odom, 1995) and chemistry (Goh, 1993; Nicoll, 2001; Sanger & Greenbowe, 1999). The means to meet the educational challenges spelled out by educators and educational researchers has obviously varied, but throughout the twentieth century, the use of technological innovations has been an increasingly frequent strategy (Petraglia, 1998a, 1998b).

Given all the time and effort invested in these matters, however, positive and stable results from the use of educational technologies are remarkably few. To underscore this observation we would like to point to a claim by Euler and Müller (1999) who hold that, within the area of physics education, the technology known as *probeware* is the *only* computer-based learning environment that has a proven general positive learning effect. Adding to the picture, that, the area of physics education is intensely studied, renders the remark by Euler and Müller even more conspicuous. Thus, as a general pattern, students seem to be invariably immune to any simple technological treatments; despite whatever new technologies we introduce into our educational systems, *learning* continues to be a struggle for educators and students alike.

In spite of this rather gloomy outlook, ever-new items are added to the list of possible remedies of educational dilemmas and student difficulties. One item on this list, and the topic of the current study, is the use of *animations* as educational resources. Our specific field of investigation concerns secondary school science education and the aim is to analyze the reasoning students perform when working with animated sequences of the carbon cycle.

The carbon cycle as a topic for education

One of the main topics in curricula for primary and secondary schools for education of natural science is the carbon cycle and its vital importance for conditions concerning life on earth. Studies of the two main processes in the carbon cycle, photosynthesis (Barak, Sheva, & Gorodetsky, 1999; Cañal, 1999; Eisen & Stavy, 1993) and respiration (Sanders, 1993; Seymour & Longden, 1991; Songer & Mintzes, 1994) report that students' knowledge of these gaseous processes is poorly understood and that misconceptions are frequent. A major problem with the conceptualization of the processes in the carbon cycle is that they involve gaseous forms that are not directly observable and therefore have to be grasped trough some representational system. Textbooks most often illustrate the carbon cycle in pictures furnished with arrows describing the course of the circulating material. Given this educational framing, one can conclude that there should be potential gains from developing educational material which build on more dynamic forms of representations, e.g. computer animations. From a research perspective, however, this still remains an open question.

Aim of the study

So far, studies of animations for educational use have mainly been concentrating on the learning outcomes in quantitative terms. In this study, we attempt to study the interplay and interaction taking place when the groups of students collaborate in connection with the animated phenomenon. Interaction analyses of knowledge building in small groups is an emerging and important methodology in the area of computer supported collaborative learning (CSCL) (Stahl, 2006). Arguably, the better we understand the students' reasoning in collaborative settings about a presented phenomenon the better we can design computer support and the learning environment in which this support is intended to serve. Evaluating a new educational technology also raises the problem of how the technology influences students' conceptualization about the observed phenomenon. By analyzing the students' interaction, we aspire to gain insights into their interpretations of the depicted phenomenon. The overall aim of this study is to explore some of the pedagogical potentials, as well as limitations, of animations displaying complex biochemical processes.

Study design and implementation

As a first part of our larger research project, a pedagogical application (available at: http://www.ituniv.se/~gorkar/) was developed where visualizations by means of 3-D animations depicted some of the processes in the carbon cycle. The index page contains a text describing the main outlines of the carbon atom cycle. At the bottom is a row of clickable miniatures linking to the different animations and to the left a menu with links to the pages in the application. The pages describe the different processes of; photosynthesis, breathing, combustion and moldering. Each page has an explanatory text and underneath the captions there is a miniature image linking to the animations.

A total of 40 students attending a science course in a Swedish secondary school were chosen for the study. The students were grouped into dyads or triads, totaling 19 groups, thus allowing peer discussions and engaging the students in reflection and comparing their different views with each other. The study was conducted during a 1.5-hour study session for each group. Before starting their exploration of the animations the students were given a short instruction about how to manage and navigate within the learning environment. There was no tutorial introduction of the topic but the students had the opportunity to consult the teacher during the learning session. For about 20 minutes the students worked with the animations. During this time they were given the task of writing down what they saw happening in the different animations. After that, while still having access to the computer animation, they were requested to discuss and jointly give answers to two problems concerning the carbon cycle.

To get a richer picture of how the students interpreted their tasks and reasoned about the animations, three groups were videotaped during their co-operative work. The analyses build on the videotaped interactions and focus on how the students made use of and reasoned about the developed computer animations. The analysis of the students' interaction with each other and with the technology draws on extensive work concerning interaction analysis (Jordan & Henderson, 1995).

Results

Three salient themes are discernible in the video material of the students reasoning in connection with observing the animations and solving the given tasks. These three themes all point to problematic issues that need more attention and further scrutiny in relation to the development of specific educational materials based on animations. Our ambition with this study has merely been to identify some relevant aspects that should and will be addressed more in detail in our upcoming work.

The first issue concerns the risk of misrepresentations and focusing the attention on misleading aspects of the animation which is a problem in some respect related to the design of the technology. As the animations are mere models of unobservable molecular processes, the interpretations of these representations can result in several misleading inferences. In the material such misleading models could be discerned when some students drew undesired conclusions about the driving force behind the gaseous exchange occurring in organisms and organic material. Examples were interpretations of molecules 'blowing' into and away from a leaf and oxygen 'coming' into a fire or a dead tree and being 'consumed'. In order to depict the gaseous exchange in photosynthesis and combustion the molecules were illustrated as moving objects. For example carbon dioxide molecules are seen moving into a leaf and oxygen molecules are leaving the leaf. Providing molecules with locomotion can seem an inevitable consequence of visually illustrating an otherwise passive gaseous exchange but can lead the observer to assume such a salient feature for the actual fact.

A second observed problem was the students' different understandings of what resources they were going to use when performing a given task. In the initial task the students were working with, they were instructed to "describe what they could observe in the animations". Depending on this formulation of the assignment, there sometimes arose conflicts between previous knowledge of the subject matter at hand and what were visible and observable in the animation. An example of this conflict became visible in a discussion between two girls when dealing with the animation of breathing. The two girls at first conclude that there occurs a transformation in the lungs but then one of the girls pointed out that it actually is a more complex process involving the gas exchange occurring inside the cells. The other girl then referred to the written task where they have to explain what they see happens, in the animation. They then concluded that it is what they could *observe* that they had to report in their notes.

The last problem observed in the study could be described as a form of isolated reasoning, partly originating from the animations. As the animations show only limited parts of the complex biochemical processes occurring inside organic material, this can be a cause of delimited and somewhat erroneous reasoning, perhaps even leading to false impressions about what the animation attempts to achieve. One of the tasks performed by the students was to give an answer to the question about the origin of the carbon in the exhalation air. Most groups gave the scientifically acceptable answer that the carbon originated from the food. In one, deviant, however interesting case, the answer provided was that carbon in the exhalation air originates from exhaust emissions. When looking at the dialogue between these two boys, it became apparent that they took as their starting point the assumption that carbon atoms originates from an airborne external source and reaches our lungs trough the inhalation air. In their discussion they therefore endeavored to conceive of a source emitting carbon atoms into the air. In summary, their discussion was completely focused on the circulation of gas the in the lungs where the carbon atom never reaches the tissue cells. In one important sense, this should be seen as an adequate and fully rational way of reasoning, given that the animation of the breathing was only visualizing the gaseous exchange in the lungs. One interesting, however not studied, reflection in relation to this observation is whether the animation, in comparison to static images, more often are treated as “more complete”? From our ubiquitous acquaintance with images we know that they render occurrences that are stretched out in time rather poorly. With animations however, it could be the case that the borders between what is represented and what has been omitted are less clear.

The exploratory character of the study makes it impossible to answer the question about the commonality of these occurrences. Taken together, these observations point out a field of investigation that needs further attention. In the worst case scenario, the animation will operate as a counteracting force that – instead of supporting knowledge building and working against the formation of possible misconceptions – will do the exact opposite; it may take the role of an antagonist of conceptual development.

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From the individual to the group: tracing preservice teachers' conceptions of transformational technologies

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Abstract: This study describes the conceptions of technology held by two preservice teachers and how they may have influenced group talk and work within a collaborative technology infusion project. Analyses establish that preservice teachers saw technology as a utilitarian tool rather than a transformational one. These conceptions were influenced by their personal experiences and were not altered greatly by peer contributions. They could also be seen to influence group talk and the ultimate creation of the infusion project.

Introduction

Due to the variety of "text forms" that are being created as a result of improving information and multimedia technologies, understandings of literacy must be broadened to include a variety of discourses and meaning-making modes in order to include and emphasize different social, cultural, and material contexts. Technology has great potential for helping learners become constructive producers of knowledge rather than just reactive consumers of information because its affordances encourage the integration and reformulation of both old and new knowledge (Cope & Kalantzis, 2000; Luke, 2003; Kress; 2003; The New London Group, 2000). Although the catchphrase "technological integration" pervades the educational realm, not all preservice teachers see the value of incorporating technology in their teaching aims. If teacher educators are to foster effective, progressive uses of technology, they must first identify the conceptions that affect preservice teachers' understandings and implementations of technology. When conceptions of technology interface directly with teachers' pedagogical knowledge and practices, then technologies can move from existing as mere artifacts, to being used as significant tools, to becoming potential transformers of education (Zhao, 2003). Preservice teachers can make connections between what they already know and what they are learning and thus engage with the material in ways that precipitate meaningful and authentic learning. For example, a webquest that hosts copies of primary sources makes available to the preservice teacher the experience of engaging firsthand with those sources as a historian (in addition to engaging with them as a traditional preservice teacher). In this way, the preservice teacher may construct a learning experience that is both socially relevant and personally meaningful, and subsequently more likely to be applied in other experiences. Such affordances often aid the transformation of educational experiences from experiences where information is merely received and processed to experiences where information is authentically applied and retained.

This study explores the ways in which two preservice teacher's conceptions were received and understood by the other members of their group and how these understandings may have influenced the creation and organization of their subsequent technology infusion project. Sociocultural theories of learning place a strong emphasis on the social construction of knowledge (Cole, 1996; Greeno, Collins, & Resnick, 1996; Pea, 1993). From this perspective, the members of a group construct knowledge as they interact with each other and share information (Cole, 1996; Greeno, Collins, & Resnick, 1996). Likewise, in a joint problem space group members interact with each other in order to arrive at joint solutions to some task or problem (Hmelo, Nagarajan, & Day, 2000). Collaborative learning research also demonstrates the importance of introspective, high quality discourse because such discourse provides opportunities for constructive processing (Greeno, 1998). In this study, the technology infusion project was designed to serve as an innovative and authentic technology learning practice that would encourage preservice teachers to safely model educational technology integrations before testing them in "real" classroom environments. The project asked preservice teachers to look at the processes behind the technological media in order to determine what purposes those processes could serve in an educational context. Preservice teachers needed to work collaboratively in order to not only ask quality questions about the underlying principles of their project, but also to complete the assignment.

Methodology

Qualitative methodology was used in order to construct a detailed, intrinsic case study that allowed for intense descriptions and close analyses of these preservice teachers' conceptions within the larger culture of the educational technology course (Stake, 2000; Johnson & Onwuegbuzie, 2004). Data collection included a variety of sources: field notes, class observations, participant responses to four online, open-ended prompts, pre- and post-project interviews, and digital video of group work during the technology infusion project. The preservice teachers were enrolled in a required educational technology course designed to encourage the appropriation and integration of transformative uses of technology. Their conceptions of technology were examined in order to 1) explore the preservice teachers' understandings of technology and 2) describe and trace how these particular conceptions may have contributed to group talk and the group collaboration that shaped the creation of the final group project. The group examined consisted of 2 English education and 2 Social Studies education preservice teachers. This study focused on the conceptions of the 2 English preservice teachers in comparison to the rest of their group in order to look at conceptions of technology that may be formed within disciplines that concentrate on literacy aims. The technology infusion project encouraged each content area group to create a sample lesson plan that integrated technology for a fictional class of high school history preservice teachers. Viewing the video corpus several times allowed for the identification of potentially significant clips, were then transcribed verbatim and coded by themes. Occurrences of group talk that indicated themes that significantly alluded to conceptions of technology were selected as significant clips. . The analyses of the pre- and post-project interviews were situated against a hermeneutic analysis of the themes revealed in the other data sources in order to develop an intrinsic case study for each participant. The data was analyzed using constructivist grounded theory methodology in order to facilitate the building of dominant categories by coding turns within all of the individual participant data and group data (Charmaz, 2000).

Discussion

The participants described technology as an academic tool that could support learning practices. They described technology in general as: powerful, frightening, fascinating, facilitating, and extraneous. As a whole, the participants' conceptions of technology did not include those of a potential transformative medium that encouraged the emergence of new or changing educational goals and practices. Conceptions of technology as a facilitating tool in support of traditional literacy practices prevailed in both their individual conceptions and during group discussion of the group technology infusion project. Cross-case analyses established that the conceptions the English preservice teachers held, which saw technology as a primarily utilitarian tool rather than a transformational one, were greatly influenced by their personal experiences with technology and were not altered greatly by the content and/or theories presented by their instructor or their peers in the educational technology course. Technology was referred to as a tool that could support learning, but it was not referenced as a transformational agent that could potentially change learning experiences. Elements of their conceptions could clearly be seen in different aspects of the final group infusion project. Although the two Social Studies education group members did not exactly share all of the same conceptions about technology as the English education participants, all group members did have several conceptions in common. The most-referenced common conception was that technology best served education as a supportive tool. However, the final project created by all group members clearly exhibited elements that could be directly attributed to statements made about the utilitarian function of technology by the English education preservice teachers. Based on the analyses of both individual and group talk in the joint problem space, it did not appear that the Social Studies education preservice teachers were persuaded or intimidated by the English education preservice teachers to define and structure technological application in their project in the utilitarian way that they did. Rather, it seemed that their own, perhaps somewhat less keenly expressed (or explored) ideas about technology, were not only reaffirmed by the English education preservice teachers' voiced sentiments, but were subsequently and easily adopted as part of the group's joint solution. Despite a well-intended course curriculum, all of the preservice teachers seemed to see technology as an "add-on," rather than an integrative component. Finally, these conceptions could also be identified in the English education preservice teachers' own predications of the types of technological integration they foresaw themselves employing in their future classes.

Understanding preservice teachers' conceptions with regards to technological tools is important to future technology and education integration, especially in light of constructivist and poststructuralist calls for the reconceptualization of traditional concepts of technology, learning, and teaching (Luke, 2003). As a result of this research, I suggest that two key practices be incorporated into educational technology courses. If these two practices have already been built into an educational technology course, it is critical that they are re-examined in terms of actual instructional objectives, sequencing of both independent and dependant enabling skills, and genuine opportunities for student engagement. In the educational technology course observed in this study, it appeared that these practices were vaguely alluded to as information that the preservice teachers were assumed to have read and comprehended (e.g., transformational technology practices were discussed in one chapter of the text for this course). It was not observed that these practices were concretely and deliberately implemented or (rather importantly) modeled for the students. First, preservice teachers need to articulate and explore their conceptions of technology within a larger societal context where collaborative activity may encourage community discussion. By having preservice teachers identify and communicate their understandings of technology to others, they engage both their critical and reflexive thinking skills. Also, it may compel them to think affectively about the roles and spaces where technology intersects their lives and to think about disengaging technology from societal and cultural biases in order to understand what personal relevance technology has for each of them. Second, preservice teachers need to be deliberately engaged in collaborative, potentially transformative educational technological activities in order to expand intellectual resources available to individuals and subsequently the knowledge base from which they draw their conceptions of technology from. Activities that engage preservice teachers in inquiry projects using web-based resources, computer simulated discovery, and exploration or digitally aided measurement and analysis could be some ways of integrating technology into an educational curriculum. Applying such practices may create a potentially different and transformative technology experience to compare to other experiences that already exist in their personal histories.

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Visualisations for Team Learning: Small Teams Working on Long-Term Projects

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Abstract: We have developed a set of visualisations mirroring the activity of small teams engaged in a task. These provide a bird's-eye view of what is happening in a small team, giving insights into the way that each individual is contributing to the group and the ways that team members interact with each other. We report on our first experience of using these visualisations for a semester-long software development project course. The study revealed that students, especially those with leadership roles, found the visualizations informative and helpful and that over a third of students modified their behaviour accordingly.

Case Study Context

We are interested in the case of group learning that involves substantial long-term collaboration, over several weeks if not months, where the primary goal is to get a task done (solve a problem, design/develop something) and where the learning effects occur in the context of working on the task. In an educational context, such learning teams can be expected to (a) produce useful artifacts that constitute a contribution to socially shared knowledge (e.g., a problem gets solved), (b) to learn individually—as a side effect—about the domain the problem is contextualized in, and (c) to learn individually—as a side effect—about the team members and to develop knowledge and skill about collaboration management. On the group level, we can expect learning to occur (d) by improved team effectiveness, such as improved coordination of individual activities.

In this paper, we describe our approach to supporting collaboration management for teams that make use of electronic tools like wikis. Support can be established in many forms but, minimally, teams must be provided with the information required for learning along all of the dimensions; in particular, they must be provided with information on team processes, in addition to the task-related information. We have created a set of interrelated visualizations that display the vast amount of information stored in electronic traces such as log files in a format directly addressing team functions (Kay et al., 2006), two of which will be presented here as used in the context of an undergraduate capstone software engineering project based on eXtreme programming (Beck, 2000).

Before describing the abstract form of the visualizations, we introduce the electronic and broader environment that provided the data for our main use of the visualizations. This is a software development project where students work in groups of 5-7 over 13 weeks. Team members tend to focus on the goal of producing a software product that meets their clients' needs, rather than the group management needed to achieve this. Following the Extreme Programming (XP) approach (see http://www.extremeprogramming.org/), students endorse one or more particular XP role such as team leader (who manages the group), tracker (who tracks people's work and ensure that things are progressing as planned), the customer (who is in charge of liaising with the client), the tester (in charge of functional testing), the doomsayer and so on.

To support their tasks and communication, groups are required to use trac, a tool designed for programmers working in teams to build software. It has three, tightly integrated media: (1) a wiki for collaborative editing of web pages for general group communication; (2) an issue tracking system based on so-called tickets, where one team member creates a ticket when a task needs to be done, this is allocated to a team member and, when the task has been completed, the ticket is closed; (3) a browsing interface to a repository based upon the version control system called Subversion (SVN), for storing documents like source code, including any versions.

Visualisations

Figure 1 shows our main visualization, which we call the Wattle Tree. (The Wattle tree is an Australian native plant with fluffy golden-yellow round flowers, similar to this visualization.) Each person in the team appears as a “tree” that climbs up the page over time. The tree starts when the user first does an action on any of the three media considered. The vertical axis shows the day number and date. Wiki-related activity is represented by yellow (bright) “flowers”, circles on the left of the trees. SVN-related activity is similarly represented, as orange (darkish) flowers on the right of the trees. The size of the flower indicates the size of the contribution. Ticket actions are represented by leaves – the green lines: a dark (green) leaf on the left indicates a ticket was open by the user and a (light) green leaf on the right indicates the user closed a ticket. The length of the left leaf is proportional to the time it remained opened. Those still open are shown at a standard, maximal size (e.g. the ones around day 41 in Figure 1).

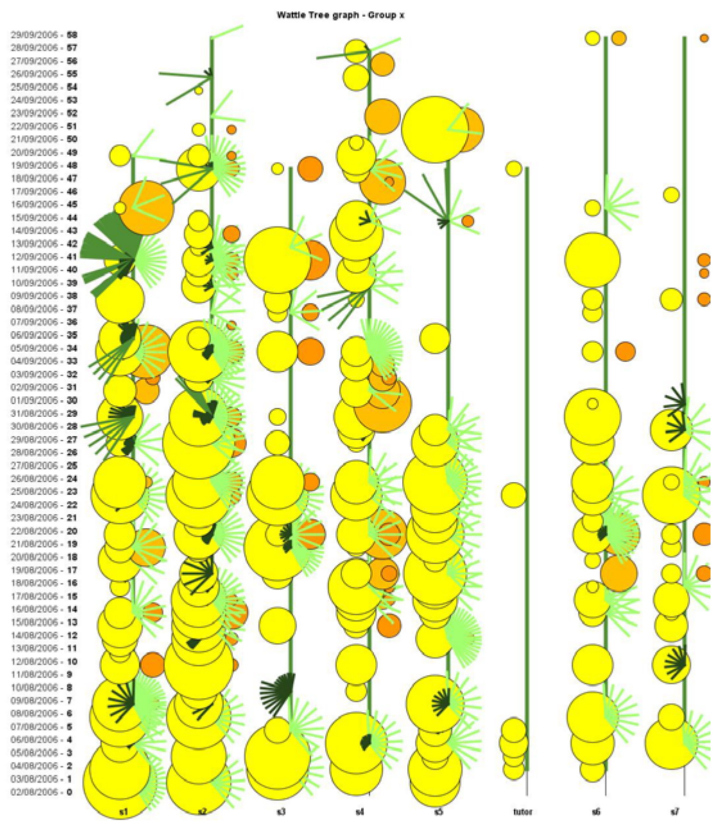

Figure 1.Wattle diagram

Wattle trees do not contain information on who issued tickets to whom, and who contributes to a wiki page. In order to visualize this kind of information, we use what we call an interaction network, inspired by the graphical notations used in Social Network Analysis (Scott, 1991). The network is modeled as a graph based on nodes representing team members, with each team member occupying a fixed position. So, for example, the person at 12 o’clock in Figure 2 and Figure 3 is the same in each of these visualizations. Lines between these nodes indicate interaction between these team members. We define interaction to occur if the pair modifies the same wiki page or SVN file or both perform actions on the same ticket. The width of the edge is proportional to the number of interactions between them. For a given resource, the number of interactions is calculated as n = min(n1, n2) where n1 and n2 are the number of times user1 and user2 modified the resource.

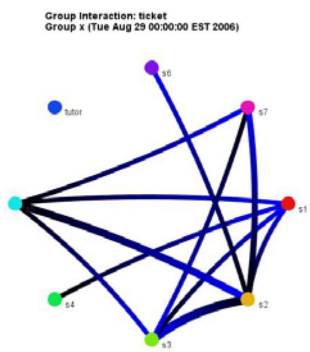

Figure 2. Interaction network for tickets

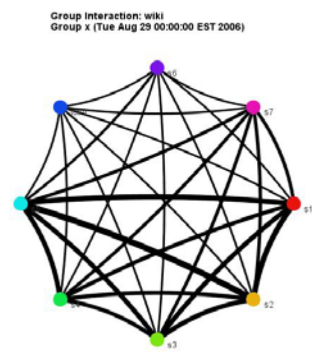

Figure 3. Interaction network for wiki pages

First experiences using the visualisations

We report here experiences from a semester-long project course (capstone project) where teams used trac. There were 7 groups of 5 to 7 students in each team, with a total of 44 students making it to the end. Three of the seven groups showed great enthusiasm for the visualisations and asked to be able to generate them on demand (This is not yet possible). The students indicated that the visualizations were helpful for the tracker (the person who has to ensure that work is progressing as intended) and the manager (who distributes the workload). There has also been spontaneous reference to the visualizations in relation to some difficulties in groups, particularly in the case of seeming occurrences of social loafing, with an individual failing to carry their fair share of work in the group. Students have also stated that the visualisations help individuals to see the amount of work they have contributed to the group, to compare it with that of others and to provide some quantitative measurement for balancing the group workload. Some students explained that they would like to see how the diagrams change after they have contributed a fair amount of work and see how this amount compares with the others. One group mentioned that the lack of contribution from a member showed up on the Wattle Tree. The group liked to see the evidence. The member said he took it as a wake-up call, and intended to participate more. The main negative feedback was related to the fact that the visualizations are based on simple counts of the amount of activity and there is no measure of quality. This is a very valid concern, but we point out that the numbers are interpreted by team members who are very familiar with each others' work.

Conclusions

One of the main contributions of this work is the set of visualizations of activity in small groups working over sustained periods. The Interaction Network visualizations, derived from social network diagrams, are novel in their presentation across the media available in trac. The Wattle trees are new, although they were inspired by Donath (1999). Perhaps the most important contribution of the paper is the insights into how such visualisations are actually used by teams. We found that our teams appear to need to be introduced to these tools. This goes hand in hand with the need to motivate team members to appreciate the importance of collaboration management.

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Using Computer-Based Math Games as an Anchor for Cooperative Learning

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Abstract: This paper reports an empirical experiment that examined the effects of cooperative computer-based math game playing, in comparison to cooperative paper-and-pencil drilling, on cognitive, metacognitive, and motivational math learning outcomes. 141 5th graders were randomly assigned to the two experimental groups and undertook the treatment activities for eight 45-minute sessions during four weeks. The results indicated that game-based cooperative learning context was more effective in promoting positive attitudes toward math.

Introduction

Despite the large number of studies about the use of instructional games alone and cooperative learning alone, studies combining these two variables are still limited. According to Crook (1994), computing technology may serve to support cooperation by providing students with something he calls points of shared reference. He further claims that in a traditional classroom situation there are not enough anchor points available at which action and attention can be coordinated for successful cooperation. In agreement with Crook's argument, an examination of the capability of using computer-based games as a mediating tool that help students to focus their attention to mutually shared objects (Jarvela, Bonk, Lehtinen & Lehti, 1999), thus enhancing their cooperative learning experiences, is warranted.

A major finding of the reviews and meta-analyses of CSCL studies (Cavanaugh, 2001; Whelan & Plass, 2002) is that there are very few real experimental studies comparing learning outcomes in between computer based and traditional learning situations. In most of the studies on CSCL the authors described the computer tools used and the working processes, but there was seldom rigorous experimental evidence about the effects of these learning environments. On one hand, the developers of CSCL environments were able to obtain a rich view into the interaction and collaborative knowledge-building processes through content analysis, ethnographic approaches, discourse analysis, as well as social network analysis; on the other hand, it is difficult to extract generalized main findings from this rich qualitative data (Koschman, Hall, & Miyake, 2002). Therefore, using the traditional experimental model of evaluating the effectiveness of the CSCL environment (such as cooperative learning around computer-based math games) is still a critical and complementary approach for the research community.

Research Purpose and Design

This research investigated whether cooperative computer-based math game playing, in comparison to cooperative paper-and-pencil drilling, would be more effective in facilitating comprehensive math learning outcomes. A pretest-posttest experimental design was used to examine the effects of two cooperative learning contexts (computer game-based playing and traditional paper-and-pencil drilling) on participants' performance at the criterion measures – standards-based math exam performance, attitudes questionnaire, and metacognitive awareness survey responses.

Participants

141 5th graders were recruited from four rural school districts in America. Participants varied in gender, socio economic status, and prior math ability level: 51% were female, 38% were economically disadvantaged, and 43% were below proficiency in prior math ability level.

Computer-Based Math Games Used

ASTRA EAGLE was a series of web-based math games developed by the Center for Advanced Technologies at one of the sampled school districts. The games were designed to reinforce academic standards for mathematics required by Pennsylvania System of School Assessment (PSSA), which is a standards-based criterion-referenced assessment required by all public schools in the Commonwealth of Pennsylvania. The games were developed as single-player games using Macromedia's Flash and can run in any recent major Web browser.

In this study, four mathematics games within the ASTRA EAGLE set that target 5th grade students were used. These mathematics learning games contained a variety of tasks targeting math concepts comprehension and skills application. Most tasks were contextualized in roles and actions relevant to school students. For instance, in a game called “Up, Up, & Away” children acted as pilots who traveled by balloon. One problem embedded in the game was to estimate the traveling speed, “If the balloon was traveling at 14 miles per hour and then sped up by a factor of 2 and then added another 1 miles per hour, how fast would it be traveling?” Another example was the task of locating X and Y coordinates in a game called “Treasure Hunt”, where game players could follow a hint “Go to X15, Y3 on the map” to dig for treasure. Immediate feedbacks were provided upon students’ actions. The games were challenging: children had to push themselves to beat the computer game or get to the next highest level.

Instruments

A 36-item “Game Skills Arithmetic Test (GSAT)” was constructed based on the PSSA. It measured cognitive math skills that the computer games were designed to reinforce. The GSAT test was web-based and comprised 36 multiple-choice questions. A panel of 5th grade math teachers from the sampled school districts had vetted the content validity of the test questions. The KR-20 reliability of the test in this study was .86. An inventory on attitudes toward the subject matter was a modification of Tapia’s “Attitudes Towards Math Inventory” (ATMI, Tapia & Marsh, 1996). This five-point Likert-scaled inventory is a 40-item survey, investigating students’ feelings toward mathematics according to four identified factors labeled as: self-confidence, value, enjoyment, and motivation. The KR-20 reliability of the inventory in this study was .97. Metacognitive skill were measured by the Junior Metacognitive Awareness Inventory (Jr. MAI) Version A (Sperling, et al. 2002). The Jr. MAI Version A is a 12-item self-report questionnaire about the way students learn, intended for use in grades three through five. Respondents are required to estimate on a 3-point Likert scale (1 = never; 3 = always) the frequency with which they engage in metacognition when learning and studying. The instrument’s reliability in this study was .65.

Procedures and Treatments

The researcher with the teachers administered GSAT, ATMI, and Jr. MAI as a pretest. Participants then were randomly assigned to one of the two experimental groups: cooperative game-playing group and cooperative paper-and-pencil drilling group. Participants received orientation to familiarize themselves with the cooperative learning task, and if applicable, the math games environment. Participants then were then required to play one math game during two 45-minute sessions each week for four weeks or do equivalent paper-and-pencil math drills during two 45-minute sessions each week for four weeks.

1. *Cooperative game playing*: A close simulation of the Teams-Games-Tournament cooperative learning strategy (DeVries & Slavin, 1976) was used. Specifically, students were stratified by their math ability level and gender, and then randomly assigned to a four- or five-member team. At the beginning of each game session, students collaborated with teammates for 15 minutes: sitting before the same computer and practicing with the games. For the remainder of the 30 minutes, game teams then competed against one another; each team member was assigned to a desktop computer at a tournament table to play against other teams’ representatives. At any tournament table the students were roughly comparable in achievement level. At the end of every gaming session, the players at each table compared their gaming scores to determine their rank order which was then converted into points. The points that the players earned were added to compute a team score. The team scores were ranked and listed in a class newsletter, and distributed to the class at the beginning of next treatment session. Top team got a winner certificate.
2. *Cooperative paper-and-pencil drilling*: Like cooperative game playing group, participants formed heterogeneous teams (mixed in ability and gender) and did teams-games-tournament activities. The only difference is they did paper-and-pencil math drills instead of game playing. Drill questions were retrieved from the four math games in ASTRA EAGLE and printed on paper sheets.

After four-week experiment treatments, all participants retook the GSAT math test, ATMI attitudes inventory, and Jr. MAI metacognitive awareness inventory in the posttest.

Results

A single Multivariate Analysis of Covariance (MANCOVA) was conducted to examine the main effects of the cooperative learning contexts (computer-based game playing versus paper-and-pencil drilling on Game Skills Arithmetic Test (GSAT) performance, Junior Metacognitive Awareness Inventory score (JrMAI), and Attitudes toward Math Inventory score (ATMI). Participants' pre-treatment scores in GSAT, JrMai, and ATMI were used as covariates. The MANCOVA results indicated overall significant effects of the cooperative learning contexts on the outcome variables of mathematical learning, $F(3, 134) = 5.03$, $p < .01$. The results also indicated that cooperative computer-based game playing facilitated positive attitudes toward math learning significantly more than cooperative paper drilling ($F(1, 136) = 14.50$, $p < .001$), but its advantage on cognitive math test performance and metacognitive awareness was not significant ($p > .05$). Table 1 shows the descriptive statistics of the two experimental groups in terms of ATMI attitudes toward math inventory score, GSAT math test performance, and JrMai metacognitive awareness inventory score.

Table 1: Comparison of the two experimental groups

	Cooperative Paper-and-Pencil Drilling n = 67		Cooperative Computer-Based Game Playing n = 74	
	Mean	SD	Mean	SD
Pre Test				
Test [a]	18.00	5.70	18.97	5.46
Attitudes [b]	145.03	26.91	152.03	24.90
Meta-cognitive Awareness [c]	28.06	3.51	28.88	3.02
Post Test				
Test [a]	19.13	5.66	20.95	5.50
Attitudes [b]	144.73	28.88	161.76	23.38
Meta-cognitive Awareness [c]	27.45	3.77	29.01	3.46
Adjusted Posttest*				
Test [a]	19.66	--	20.47	--
Attitudes [b]	148.33	--	158.50	--
Meta-cognitive Awareness [c]	27.83	--	28.66	--

Note: * Adjusted means using three pretest measurements (GSAT, ATMI, Jr. Mai) as covariates.
a. The full score of GSAT math test is 36.
b. The full score of ATMI attitudes inventory is 200
c. The full score of Jr. Mai metacognitive awareness inventory is 36.

Based on this study results, it could be argued that using computer-based educational game as a motivational tool for cooperative learning is more convincing than using it as a cognitive or metacognitive one. There was no enough statistical evidence suggesting that computer-based game playing will facilitate or obstruct cooperative learning. However, it should be noted that the games used in this study were originally designed as single-player games. The game characteristics of a single-player game may influence its supremacy in serving cooperative learning format. Therefore cautions should be exercised when generalizing the study findings to interpret the interdependence between a multiplayer game and cooperative learning context.

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Exploring Self-Regulation in Group Contexts

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Abstract: Research on group processes that advances student learning has the potential to support current efforts aimed at introducing technological innovations into classrooms that encourage student collaboration. The current study focuses specifically on group processes that emerge during collaborative learning by exploring how groups use behavioral and cognitive regulation when working on collaborative tasks. Within our analyses, we examined evidence for group self-regulation among two 4-person groups of sixth grade students while they worked on three different group activities as part of a mathematics unit on statistics and graphing. Results suggest that groups made consistent efforts at regulating their learning and engagement, but that the overall quality of group regulation varied. In addition, our findings support the application of the general categories of behavioral and cognitive regulation to regulatory processes in groups, but suggest that specific aspects of self-regulation may be especially important in group contexts.

Introduction

As technological tools begin to promote student collaboration, it is important to look to the group process literature in considering how students learn in group settings. Educational research emphasizes the benefits of collaboration for learning because it provides students with the opportunity to question, share, and justify ideas (Cohen, 1994). However, many of the research questions concerning the specific group processes that contribute to advancing student learning remain unresolved (Cohen, 1994; Erkens, Prangsma, & Jaspers, 2006). One reason for this problem is that researchers have not carefully considered how learning processes may differ between individual and group settings. Research on self-regulated learning suggests that self-regulation can enhance learning in traditional classroom settings (Pintrich, 2000). It seems plausible that self-regulated learning would be beneficial in group contexts as well. For example, the inherent social nature of students working in groups makes it likely that off-task behavior will frequently occur. Moreover, the task of planning and monitoring the group's work may be especially important because it is critical that the group ensure that all students are benefiting from the group task.

Accordingly, the purpose of the current study is to investigate how small groups regulate their behavior and cognition. We use prior research on individual self-regulation as a guide to understanding group self-regulation, and thus distinguish between behavioral and cognitive regulation (Pintrich, 2000). More specifically, behavioral regulation refers to a student's efforts at sustaining his or her on-task behavior and persistence by attempting to eliminate distractions or using self-talk as a form of encouragement. Cognitive regulation consists of the processes of planning, monitoring, and evaluation. Planning refers to a student actively and consciously setting task-specific goals for learning, performance on the activity, and time use. Monitoring refers to a student's active evaluation of understanding or progress. Student monitoring of understanding refers to checking whether he or she understands the content being studied and the skills needed to engage in an activity. Students can also monitor their progress toward specific task requirements and time. Monitoring may influence a change in strategy or a revisiting of the task directions. Finally, effective self-regulators evaluate and reflect on their task performance once a problem or the task has been completed.

Method

The research reported here is part of a larger study investigating students' motivation and learning in small groups in mathematics (Linnenbrink, 2005). For the current research, two groups of sixth grade students (n=8) from the same classroom were videotaped while working in their small groups for three days across a mathematics unit (129 minutes for each group). Both groups were heterogonous with regard to prior math knowledge. Both Group A (Charles, David, Angela, and Rochelle) and Group B (Sam, Peter, Briana, and Julie) consisted of two males and two females (1).

Groups were observed working on three different tasks designed as part of a larger unit on statistics and graphing. This mathematics unit focused on teaching students how to read and interpret a variety of types of graphs (e.g. bar graphs, line graphs, stem and leaf plots) and how to calculate basic statistics such as the mean, median, and mode. The 3 group activities were designed to include both lower (calculate the mean, median, mode) and higher-order questions (e.g., after calculating the mean, median, and mode for each graph, students were asked to write a paragraph describing which statistic best represented the data presented in the graph).

The data were analyzed using a qualitative approach, which allowed us to explore and describe the group self-regulatory processes that emerged. Narratives were prepared that thoroughly describe the group's interactions. Together, the two co-authors coded the narratives along a set of 8 dimensions (e.g. quality of group interactions, social comparison) (2). For the current study, we focus on the self-regulation dimension, but note the interplay with other dimensions when appropriate. We distinguished an individual's attempts to regulate his or her own learning and engagement from a group's attempts to regulate the group's learning and engagement. The latter, group self-regulation, is the focus of the current paper. Narratives were sub-coded for three aspects of group regulation: planning, monitoring, and behavioral engagement (3). Group interactions were characterized as *planning* when there was evidence of students discussing task directions, assigning group roles, and planning how to go about solving the problem(s). Group *monitoring* was coded when students were seen checking their work after completing a component of the task, or when monitoring progress or the time spent on the task. We did not code the narratives for evidence of *evaluation* because we did not observe the completion of the tasks. Group efforts at *behavioral engagement* were identified when students tried to encourage the group or an individual student to re-engage in the task. As a final phase of the analysis, the authors reviewed the codes and created summaries for each category for each of the narratives. The summaries provided an in-depth description of the types of group self-regulation that occurred in the group.

Results and Discussion

Behavioral regulation

Our analyses indicated that there were frequent attempts to behaviorally re-engage the group and that these attempts seemed to play an important role in the functioning of the group. The strategies used to behaviorally regulate the group included both low and high-level strategies. Groups frequently used brief, low-level attempts in order to get students back on task. For example, students used quick reminders such as, "Come on, we need to get back on task!" or "Hurry up!" in order to encourage re-engagement with the task. With respect to high-level behavioral regulation, we observed three patterns. One pattern was for students to encourage behavioral engagement by trying to involve group members in the task. For example, after realizing that Charles was disengaged, Rochelle suggests to Charles that he could help her write the summaries of the graphs. A second observed pattern was for group members to support a feeling of group cohesion or sense of team. For example, Briana encouraged persistence saying "Come on, if we work hard we can get this done," suggesting "let's get this done" together. In a third pattern, students used between-group comparison by turning to other groups and comparing their group's progress as a way to encourage persistence and engagement. For example, Briana compared their speed to other groups by suggesting, "Okay we have to get back to work. Everybody else is ahead of us." There were some drawbacks to trying to sustain progress and engagement, however. Thoughtful task related questions and attempts at monitoring understanding were sometimes thwarted by group members' concerns about time and maintaining engagement. For example, while Peter and Briana were selecting data for the line graph, Peter asked a thoughtful question about how to make a line graph using the selected data. Rather than responding to the question, Briana interrupted him in the interest of continuing to make progress on the task. In this manner, behavioral engagement sometimes served to focus the group on completion rather than on attempts at deepening understanding. Overall, the high-level strategies used to behaviorally engage the group may have been more effective because these collaborative attempts seemed to sustain on-task involvement.

Cognitive regulation

Planning. Many of the patterns observed for group planning were similar to those proposed by the literature on individual self-regulation. The group context, however, afforded a unique window into the *process* of planning. For example, group members worked together at the beginning of an activity to interpret and clarify the presented task directions. By interpreting the task directions together, Briana and Peter were able to recognize that they had misinterpreted the directions. In addition, students in the group also planned how to go about solving the task. Here, the group discussed the order in which to progress, planned their next steps, or assigned group roles. Groups also demonstrated evidence of more advanced planning within the group. For example, when planning to draw the next graph, groups discussed the type of graph which would best represent a set of data. In an interesting pattern, we also observed interplay between monitoring and planning, such that students revised their plans for working on the task when their monitoring indicated a problem. For instance, when checking whether their group had done the task correctly, Group B realized that they had drawn the wrong graph and that they needed to alter their plan. The relation between monitoring and planning seemed more advanced because students revised and adapted their plans in response to monitoring and task feedback.

Monitoring. As with behavioral engagement, there were varying patterns of monitoring observed. Less effective monitoring included superficial forms of monitoring that did not serve to deepen understanding. For example, group members would simply take over a fellow student's work without taking the time to explain their corrections and provide feedback. There were also attempts at group monitoring that were tempered with a negative tone or signs of disrespect. Students were observed grabbing other students work, taunting their group members, and voicing put-downs of a student for incorrect responses. For example, Angela explicitly told her group that they would need to check over David's work "because it is probably all wrong." In this way, less effective forms of monitoring seemed to occur during negative group interactions.

We also observed more effective attempts at monitoring. First, effective monitoring involved the collaboration of the whole group in monitoring their progress, rather than one group member taking the responsibility. Group members were observed leaning in and working together to check the group's work on the task. For instance, Group B questioned the mean that they had calculated because it ended in a repeating decimal. As a result, they spent 10 minutes re-working their calculations using the provided calculator, re-calculating the mean by hand, and explaining why they continued to get the same repeating decimal. This example highlights that some collaborative efforts at monitoring understanding were prolonged. In addition, this instance revealed an interesting role of technology. The group seemed to question the accuracy of the calculator and wanted to ensure that they would receive the same answer when calculating the findings by hand. As such, the use of technology in this group seemed to encourage monitoring, as students questioned their findings. While this may seem counterintuitive in that many students assume that a calculator or computer "can't be wrong," our findings are encouraging in that the technology seemed to encourage rather than discourage group regulation. A second pattern of effective monitoring was seen when group members provided informational feedback in response to incorrect answers and then worked together to incorporate the suggested changes. For instance, Briana checked Peter's work, made suggestions about how to clarify the bar graph, and then they both worked on incorporating her feedback. Finally, we also observed that between-group social comparison contributed to effective monitoring. Group B used social comparison as a source of feedback regarding their task progress. For example, Briana noticed that they had finished the task before other groups, saying, "Are we doing something wrong…then why are we the first ones done?" This prompted Peter to turn and deliberately monitor the work of other teams to check if there was a section of the task that they had not yet completed. While there were instances when groups engaged in between-group social comparison that did not serve an informational purpose (e.g. competing with other groups), this example indicates that social comparison may serve a regulatory purpose in that it led the group to revisit the directions and check their work.

Overall, our results indicate that the two groups made consistent efforts at regulating their group's engagement and learning, demonstrating a high quantity of group regulation. While these attempts at group self-regulation were frequent, the overall quality of group regulation varied, with instances of high quality planning, monitoring for understanding, and behavioral engagement occurring less frequently. In addition, our findings suggest that the general categories of behavioral and cognitive engagement that were developed for understanding individual self-regulation can be applied to interpret regulatory processes in groups. Different aspects of self-regulation, however, appear to be especially salient in group contexts. For example, efforts at behavioral engagement were recurring and played an important role in group functioning, most likely because off-task behavior is common in group contexts. Given the descriptive nature of the current study and the small sample, it will be important for future research to confirm these patterns and to consider how group regulatory processes relate to other aspects of group functioning. As technology becomes integrated into collaborative learning, future research should also investigate whether these same group regulatory processes can be applied to technologically-rich collaborative contexts.

Endnotes

(1) Please note that all students' names are pseudonyms.
(2) We are not able to calculate an inter-rater reliability score because all narratives were coded together. Any discrepancies were resolved through discussion.
(3) Additional details regarding these codes and the process of coding are available from the authors.

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Interaction Rules: their place in collaboration software

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Abstract: One major form of social capital that is central to the development of communities is the set of structures devoted to; norms of interaction, making these norms overt and regulating interaction. The creation of these structures is deeply linked to notions of trust, which has been identified as a major factor in the behaviour of successful virtual teams. Because (virtual) teams are complex, the types of interactions that suit a particular team may or may not be predictable. The first author has created Phreda, software that permits group members to create interaction rules in the form of production rules. These rules are then given to an expert system shell that matches these rules against resource use parameters in the group's online collaboration environment. This software as well as results from a first pilot study are described.

Democratic Interaction Rules

What knowledge can a software designer draw upon to understand social interaction and, then, encourage trust and bonding in a virtual environment? Sociological and social psychological analyses help the designer to understand how and why people collaborate. The CSCW and CSCL literature describes the qualities of "successful" teams – those exhibiting optimal performance – as including open communications, conflict management, (Yeatts & Hyten, 1998) trust and risk taking. Trust is both a cause and an effect of healthy team interaction (Fernández, 2004). McGrath's Time, Interaction and Performance theory identifies team behaviour as fulfilling three functions – task or production work, team support and individual support (McGrath, 1991). Yeatts and Hyten call the behavioural patterns norms (Yeatts & Hyten, 1998). The norms apply to behaviours such as attendance, the acceptable level of smalltalk and the level of risk taking. They are often unspoken expectations shared amongst the team. Giddens' structuration theory explains how patterns become established in a community. Structuration is the process of producing and reproducing structures of a social system by 'agency' or use. Structures do not exist without people using them. They are systems of ongoing action being produced and reproduced through time.

These considerations led us to the following design guidelines:

- Since teams are complex systems that develop dynamically over time, it is very hard, if not in principle impossible, to prescribe optimal norms; instead, such norms (collections of interaction rules) need to emerge from the group itself.
- Even if useful for a team, the cognitive load of devising rules and then learning the interface for their implementation would be a major disincentive for team members to engage with the module (Sintchenko & Coiera, 2003). Hence, groups should be 'seeded' (Fischer & Ostwald, 2005) with an initial set of rules and be provided with means to change them as they see fit.
- It is awkward for members of democratic, peer-based groups to "police" the compliance with the rules even if these are self-imposed. The monitoring of compliance should hence be given to an outside "authority", a software component that monitors the interaction rules.

In the next section, the software tool Phreda is described that realizes these design guidelines as a first implementation.

The Software Tool Phreda

Phreda is based on a production rule formalism. Production rules were chosen as the implementation language for interaction rules because they allow the user to attach symbolic labels reflecting the intended meanings to sets of measurable conditions. Measurable conditions are those that can objectively be found in electronically recorded activity traces as stored in a database. The conditions express the state of the collaborative tools in the software, for example the number of times a person logs into the website. The action part of a rule expresses consequences, such as sending messages to specific group members. Actions can also result in predicates describing a group's state at a level higher than the measurables, and the predicates can in turn be used in the condition part of other rules. Allowing team members to freely create, edit and delete rules permits the dynamic expression of meaning and importance to evolve.

For example, the 'give_feedback' rule notifies an individual if they are classifying less than a tenth of their postings as 'feedback' and suggests that they offer more support to their fellow members.

Figure 1 shows how a group member, when logging into to the collaboration environment, sees the consequences of rules firing. These are a number of messages generated by the expert system. The messages are based on the team state - how the group used the collaboration tools available, such as a discussion board and a document upload area.

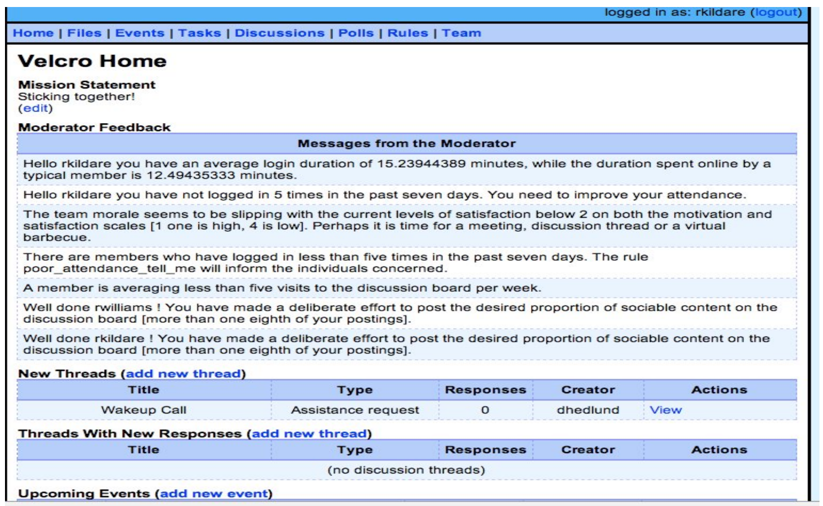

Figure 1: Software home page showing links to tools for managing people, time, artifacts and actions, also the rule management module. The output from the software moderator is displayed under the heading 'Messages from the Moderator' with current discussions, tasks and events below.

Phreda is a composite of a rule editor, a collaboration environment and a server-side rule processor. The collaboration environment contains cut down versions of typical groupware tools and an awareness graphics tool. The rule module is separable and can be used in other projects, with most of the effort being the interface integration of the rule editor. Typically collaboration software has tools to manage people, events, task allocation, communication and storage for personal and team files. These are represented in the trial implementation. Also represented are graphical awareness tools, which are still predominantly in the research domain (Reimann, Kay, Yacef, & Goodyear, 2005). Their effectiveness almost certainly guarantees that the genre will be represented in mainstream software.

Trials to Date

Two teams have used the software to date: a senior secondary team of 6 co-located students and their teacher, and a team of 8 mainly co-located academics Both of the teams were given the opportunity to make changes to the rules or to request that the author make changes. The seed rules were designed to address issues of domination and freeloading and some of the desirable qualities of the communication upon which collaboration depends. Attendance rules were set so that individuals not meeting a benchmark were told so personally, the team told anonymously.

Observations

The team of teenagers has a much larger proportion of 'social' contributions in its discussion board. It is tempting to think that there may be recognisable team types, given the pictures of usage and types of communications. It should be noted that there are 96 individual measures available for team members to use when creating rules, and therefore 96 variables that could define a team's state. There is great potential for theory driven testing.

The first (student) team did spend time looking at the rule module, but neither made, nor requested any changes to the initial seed set. Their teacher observed that the team was helped by the structured format of the system. The inbuilt rules helped them keep - if not to task, then at least regularly logged on and providing messages to each other. The students' questionnaire responses indicated that about half the participants saw value in having the rules.

The academics' team did not request any rule changes either, but made comments that reflected a better understanding of the value of interaction rules. Perhaps the most telling feedback during the four weeks was after members were encouraged to vote their levels of satisfaction and motivation. The rule 'morale_slipping' fired suggesting among other things, a 'virtual barbecue' (details in 'Rules', above). One member commented in the discussion forum: "I must admit to being a little sceptical about the automated rules and the messages they generate. ….However, I now appreciate their value as triggers for human intervention..." This was followed by an attempt by another of the members to organise a face-to-face social event (a non-virtual barbecue). The results of these initial trials of software to support team behaviour when team participants are interacting as a virtual group have been surprisingly encouraging. The trials were of limited duration and size and participants mostly had the option of interacting physically as well. However, the software performed robustly and the size of the trial did not prevent it from constructively affecting behaviour. It seems that the software can not only support research into the performance of general collaborative tasks but also theory driven research, in particular a more rigorous experiment that explores hypotheses related to trust, conflict or performance. There appeared to be some educative value in understanding the importance of interaction rules to the collaborative process as a result of simply having the seed rules present.

As predicted, both teams hesitated to be engaged in the formation and editing of the rules. Cognitive load can be overcome by a rule expert, but heuristic knowledge is scarce. A number of machine learning techniques, however may be useful for ascertaining patterns in rules that correlate with types of teams. A software expert would use the rule sets and the states of many software moderators as the basis for its learning. It would recommend rules. Underlying concepts have been inferred in model-free expert systems in both hierarchic (Richards, 1998) and mesh structures (Suryanto, 2004). Decision trees are also appealing as a means of machine learning symbolic data. The software expert would permit recommendations to evolve, adapting to changes experienced within the team.

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Sharing Visual Context to Facilitate Late Overhearer's Understanding of the Handheld-Based Learning Activity

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Abstract: Peripheral participation is fundamental to collaborative learning. In the classroom, we see two situations in which peripheral participation is essential: *formative assessment*, during which a teacher attempts to assess the utility of an ongoing activity and intervenes if necessary; and *peer-monitoring*, during which a student attempts to learn what other students are doing. When augmenting the classroom with handheld, wireless computing devices, handling peripheral participation becomes more difficult. The proposed new handheld network service, *Look*, allows a late overhearer, who has not witnessed the creation of common ground, to monitor the interaction between group members already engaged in a collaborative situated learning without interrupting. Laboratory experiences with our prototypes indicate that *Look* balances lightweight implementation, ease of use, and utility in a way that could enhance classroom communication and learning.

Introduction

In discourse, people frequently switch their roles between *central participation* (such as speakers or addressees) and *peripheral participation* (such as overhearers or bystanders). Many computer-supported collaborative learning (CSCL) or computer-supported cooperative work (CSCW) tools focus on supporting central participants in a communication; however, none that we know of focuses on peripheral participants—that is, those who are attending to the conversation overtly or covertly but are not current addressees or responders. Considerable evidence exists that such participants have different access to information and different cognitive burdens than do central participants. However, very little is known about how to support their needs, especially in light-weight interactions. In classroom group activities, active changes of social roles occur often. When we introduce handheld technology, we change the affordances available to peripheral participants. In the context of task-oriented discourse processes with handheld computers, in this paper we focus on one type of peripheral participant: an *overhearer*. We (1) analyze the challenges faced by overhearers, (2) suggest a possible solution to overcome the challenges of overhearers within the constraints of our vision of classroom use, and (3) report experimental results showing the proof-of-concept of our solution in an abstracted form.

Restrictions Faced by Overhearers

The problem of *overhearer sufficiency* occurs when two people engage in a primary task involving face-to-face focused interaction using handhelds as well as speech, while a third person, the overhearer, must monitor or join the interaction. In the classroom, this problem takes two forms: *formative assessment*, during which a teacher attempts to determine whether the activity happens in an appropriate and sufficient manner and intervenes if it does not, and *peer-monitoring*, wherein a peer attempts to learn what is happening and join the activity. At its most general, the problem can arise whenever one or more people focus on information that cannot be seen by a latecomer, making it difficult for the latter participant to gauge interruption and thus raising the effort involved in attaining sufficient common ground for informed participation.

According to Schober and Clark (1989), in actively collaborating to reach common ground discourse participants possess an advantage over an overhearer because they have understood each other's intentions. Simply put, discourse participants engage in a process of gathering the moment-by-moment evidence necessary to ensure that what is said is understood. For example, periodically a speaker might check an addressee's understanding before proceeding in the conversation and an addressee might also respond to a speaker to clarify points of confusion. This paradigm presents the collaborative view of language usage.

In such a collaborative situation, overhearers face several disadvantages in understanding what is said. First, an overhearer has limited resources in grounding the mutual beliefs, knowledge and assumptions required for current purpose of understanding conversation. (Grounding refers to the interactive exchange of evidence by discourse participants regarding what is understood.) Overhearers cannot join the process of coordinating between a speaker and an addressee. Instead, they receive only what is given by central participants (i.e., speaker and addressee). Second, overhearers cannot control the pace of the conversation, and once they lose track of the content, their misunderstandings can accumulate easily. Overhearers must contend with each speaker's next utterance while trying to complete understanding of the last one. They do not have an opportunity to keep the speaker informed of the state of their confusion and clarify misunderstandings. Third, although an addressee can determine what a speaker means from conclusive evidence of their common ground, an overhearer, on the other hand, can only conjecture about what the speaker means using inconclusive evidence. This problem intensifies if overhearers were not present to witness the buildup of common ground between conversational participants. Without knowing what constitutes the speaker's and addressee's common ground, the overhearer finds it difficult to determine exactly what the speaker means. In most, if not all cases, the overhearer's only recourse is to conjecture based on his own assumption of common ground between a speaker and an addressee.

Handheld Devices

Since we are supporting both monitoring and the potential for joining the conversation adeptly, we are concerned with device mobility. Handhelds have a relatively restricted bandwidth for wireless communication. Furthermore, we need utmost simplicity in usage. Therefore, we must ask about the utility of *minimal* representations that enable peripheral participation. Full monitoring is not an option.

To meet these concerns, we designed a new handheld network service called *Look*, which provides overhears with the ability to engage in real-time capture of activities and focal artifacts from other handheld screens by infrared (IR) beaming or radio frequency (RF) communication. *Look* allows peripheral participants to get a snap shot of another person's screen. This synchronized visual co-presence can establish that the items or concepts indexed are within the joint range of attention and enable participants to focus on the topic rather than on the technology.

Experiment

We studied the utility of *Look* in a laboratory setting that abstracted and intensified the need for shared visual understanding compared its natural occurrence in the classroom. The experiment contrasted two different settings. In one, the overhearers had *Look* implemented with Bluetooth technology. In the other, they did not. The main participants engaged in a game that involved rearranging Korean characters (KCs) on the screen to put them in a specified order. Our hypothesis was that, compared to *No-Look*, *Look* improves how an overhearer understands a conversation.

Forty-four groups of three were recruited from the psychology subject pool at Virginia Tech and randomly assigned to condition. Participants in the main task were trained in the names of KCs and asked to use them in accomplishing the task. The principle test of the benefits provided by *Look* was based on accuracy—in this case, the percentage of KCs placed correctly. According to our hypothesis, the late overhearers whose handhelds were equipped with the *Look* functionality should better understand the conversation and be better able to rearrange the figures correctly. This was precisely what occurred. Through all three trials, late overhearers in the group that had access to *Look* experienced significantly fewer errors than did those who were not supported with *Look*. When the late overhearer first entered the discourse, in trial 3, those who had access to *Look* were able to place 90% (SD: 17.6%) correctly, compared 69% (SD: 24.2) of those without *Look* (F (1, 41) = 11.15, p < .002). As the task was repeated from trials 3 to 5, correct placement increased in both the groups with *Look* and without *Look*. However, statistically significant differences remained through trial 5 between groups with and without *Look* (F (1, 43) = 9.97, p

< .003 on trial 4; F (1, 40) = 9.87, $p < .004$ on trial 5). These differences suggest that the *Look* handheld network service, which provides a visual context for focal artifacts, greatly influences an overhearer's understanding of the conversation. A second test was used to gauge, in a limited way, learning. After each trial, participants were asked to choose a name for each KC. Over all three trials, the percentage of correct naming of the KCs was higher for the groups who had access to *Look*, though the effect was in some cases small. Specifically, on trial 4, an analysis of variance yielded a significant advantage, with F (1, 44) = 4.15, $p < .05$. The result showed also marginal improvements on trial 3 and 5 (F (1, 44) = 3.22, $p < .08$ on trial 3; F (1, 43) = 2.44, $p < .125$ on trial 5).

Discussion

Active participation in conversation is not the only means by which learning can occur. Because it is fundamentally a social process that dwells in contextualized settings, learning also takes place through the observation of others (Stenning *et al.*, 1999). Technologically, such an understanding demands that we shift the way we approach collaborative learning. New technology paradigms broaden the scope and style of interaction beyond the desktop into the real world, where users encounter increasingly rich contexts. For example, the mobile nature of handheld devices like a $100 Laptop, Tablet PC, Pocket PC, and Smartphone offers students new opportunities for increasing interaction and facilitating collaborative learning. Devising a solution that within any particular situation satisfies both varying human needs and capabilities and the affordances of mobile computing presents unique design challenges. In this project, we worked through the particular set of design problems, how to use handhelds to promote the rapid acquisition of common ground and shared meaning for peripheral participants.

To support overhearers, we implemented special and even idiosyncratic handheld network features and tested under experimental settings that closely approximate the range of situations that we find in classroom learning aided by ubiquitous and pervasive computing devices. The proposed new handheld network service, *Look*, allows a minimal but moderately up-to-date view of the task state. It maintains awareness, and enables improved understanding based on that awareness. User experiences with our prototype provide preliminary indications that *Look* could enhance classroom communication and learning. Two outcome measures were used to assess the benefits of a peripheral participant having the prototype versus not having it, placement correctness and naming KCs. Based upon our initial findings, we expect that our studies will contribute in important ways to the ongoing discussion among educational researchers and computer scientists in designing mobile computing systems that will enhance future ubiquitous classroom.

The project reported in this paper is part of our continuing study investigating the influence of shared visual context on the learning for many different types of peripheral participants, including side-assistants and side-participants (Kim & Tatar, 2005; Kim *et al.*, 2006). In this study, we showed a clear advantage to overhearers from access to the *Look* feature. In real classroom settings, we argue that the need for *Look* may not arise often, but is important when it does. Therefore, to avoid misunderstanding and to allow flexible entry into conversations, it is worth the difficulty and expenses of implementing what may appear to be "extra" functionality. Further, we have shown that such functionality can be useful without increasing the computational cost of continuous monitoring.

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Group Awareness and Self-Presentation in the Information-Exchange Dilemma: An Interactional Approach

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Abstract. A common challenge in many situations of computer-supported collaborative learning is increasing the willingness of those involved to share their knowledge with other group members. As a prototypical situation of computer-supported information exchange, a shared-database setting was chosen for the current study. This information-exchange situation represented a social dilemma: while the contribution of information to a shared database induced costs and provided no benefit for the individual, the entire group suffered when all members decided to withhold information. In order to alleviate the information-exchange dilemma, a group-awareness tool was employed. It was hypothesized that participants would use group awareness for self-presentational purposes. For the examination of this assumption, the personality variable 'protective self-presentation' (PSP) was measured. An interaction effect of group awareness and PSP was found: when an awareness tool provided information concerning the contribution behavior of each individual, this tool was used as a self-presentation opportunity. In order to understand this effect in more detail, single items of the PSP-scale were analyzed.

Introduction

A crucial prerequisite for nearly all settings of computer-supported collaborative learning (CSCL) is the willingness of the involved persons to share their knowledge and the information they possess. If those involved refuse to share their knowledge with the other members of a team of learners or collaborators, team work is much less efficient than it could be. Indeed benefiting from others' knowledge by reciprocally exchanging information is the very option open to team members which makes cooperative team work efficient (Hinds & Kiesler, 2002). From the perspective of CSCL it is of particular interest and relevance to analyze ways in which information exchange between team members interacting via computers can be supported (Olson & Olson, 2003).

The establishment of a shared database is one possibility when it comes to making individual team members' knowledge available to the whole group. Such a shared database enables each group member to enter information into and retrieve information from the database (Jian & Jeffres, 2006). Technically speaking, the implementation of a shared database is quite simple. Practically speaking, however, many problems tend to arise: many studies report low motivation of team members in entering information into the database and thus making it available for their group mates (Ardichvili, Page, & Wentling, 2003; Argote & Ingram, 2000; Huber, 2001; Orlikowski, 1993; Yuan, Fulk, Shumate, Monge, Bryant, & Matsaganis, 2005).

One important explanation for this poor willingness to share information with others will be presented in the following section on the so-called information-exchange dilemma. Subsequently, a concept will be discussed which may potentially be successful in influencing people's willingness to share information: the concept of group awareness. Following this, a further aspect supposed to affect people's information-sharing behavior will be presented: the need for self-presentation. This need is conceptualized as a personality variable.

An empirical section follows these theoretical considerations, beginning with a description of the methods employed in the current study. The results of the study are subsequently reported. In conclusion, the major findings are reviewed in the discussion section.

The Information-Exchange Dilemma

From a psychological point of view, a poor willingness to share knowledge with others is not a surprising observation: transmission of information is often regarded as a loss of power, and entering information into a database is additionally associated with extra time and effort. Therefore, the decision regarding whether to pass on information or not, represents a social dilemma (Dawes, 1980; Kollock, 1998; Komorita & Parks, 1995; Olson, 1965; Weber, Kopelman, & Messick, 2004). An individual group member does not benefit from sharing his/her own knowledge with others (Cabrera & Cabrera, 2002; Kalman, Monge, Fulk & Heino, 2002). On the contrary, he/she saves time and remains in a leading or advantaged position by withholding information. On these grounds, withholding information is the most advantageous strategy. An individual is able to retrieve information from the database without contributing information in turn (Cress & Hesse, 2006). However, if all involved group members decide to behave according to this self-advantageous strategy, then nobody can use the shared database and each member has to compile the needed information for his/herself. As a consequence, the group as a whole suffers from individually efficient behavior (Cress & Kimmerle, in press; Cress, Kimmerle & Hesse, 2006).

However, recent research has shown that the individual's willingness to share knowledge in the face of the information-exchange dilemma can be influenced by the use of so-called group-awareness tools (Cress & Kimmerle, in press). The notion of group awareness and the application of corresponding tools will thus be presented in the following section.

The Concept of Group Awareness

Over the last few years, the concept of group awareness has found increasing interest in the relevant literature (e.g. Begole, Rosson & Shaffer, 1999; Briggs, 2006; Endsley, 1995; Gross, Stary & Totter, 2005; Soller, Martinez, Jermann & Mühlenbrock, 2005; Tam & Greenberg, 2006). Group-awareness refers to information received by members of a group about the other group members, about mutually employed objects, and about current group processes, in order to efficiently carry out certain tasks (Gross et al., 2005). Normally, in face-to-face situations, this kind of information is directly available. In situations of computer-mediated communication (CMC) and CSCL, however, group-awareness information is only available via technical support.

Carroll, Neale, Isenhour, Rosson and McCrickhard (2003) distinguish three kinds of awareness in CMC settings and point out that each variant can be supported by certain tools:

- With *social awareness*, Carroll et al., (2003) refer to the user's consciousness of the presence of others. A tool which makes the presence of others visible (e.g. by providing photographs of the team members) can foster social awareness.
- Tools which support *action awareness* provide information about what is going on, e.g. which actions the group is carrying out.
- *Activity awareness* relates the actions of group members to the task to be performed. Activity-awareness tools therefore provide information regarding completion of the group goal: activity-awareness increases knowledge on the group's task performance.

In the current study, a group-awareness tool was used to provide social-awareness information by presenting personal information as well as photographs of the involved team members. Additionally, the tool fostered activity awareness by presenting feedback on the contributions made to the database by group members. Awareness information was presented in three conditions differing according to their richness: In the control condition no activity awareness was induced. In the group-feedback condition, activity awareness in the sense of information about *cooperative* group members was provided. And in the individual-feedback condition, information was provided concerning cooperative group members *as well as* additionally allowing for self-presentation.

These three conditions were implemented on the basis of our belief that the individual's need for self-presentation could play an important role in their willingness to share their knowledge with others. In order to test whether this is the case, self-presentation as a personality variable is considered in the current study. In the following section, the self-presentation construct will be explored, before we turn to the study's hypotheses.

Self-Presentation

Self-presentation is an important motivation of behavior in both offline (Taylor & Altman, 1987) and online situations (Joinson, 2001; Joinson & Dietz-Uhler, 2002; Wallace, 1999; Walther, 1996). Self-presentation and impression management have recently been examined in online-dating settings (Ellison, Heino, & Gibbs, 2006; Gibbs, Ellison, & Heino, 2006) and diaries in web communities (Moinian, 2006), as well as with respect to personal web sites (Marcus, Machilek, & Schütz, 2006; Schau & Gilly, 2003). Self-presentation refers to strategic activities designed to give certain impressions to other persons (Goffman, 1959). In computer-supported environments, individuals have greater control over their self-presentational behavior than in offline settings. Online interactions can thus be managed more strategically. For this reason, self-presentation is also thought to play an important role in information-exchange situations. It is assumed that virtually all people have a need for and the ability to present themselves in a certain way.

It is, however, also conjectured that people differ in terms of the intensity of this need. In line with this consideration, Snyder (1974, 1987) developed a personality construct termed *self-monitoring*. The self-monitoring (SM) of expressive behavior comprises self-observation and self-control and is guided by situational cues to social adequacy (Gangestad & Snyder, 2000). In an alternative conception of the SM construct proposed by Wolfe, Lennox, and Cutler (1986), a distinction is made between acquisitive and protective self-presentation. *Acquisitive self-presentation* pertains to the tendency to actively realize social profits, i.e. an acquisitive self-presenter presumes social reward given that she/he manages to behave appropriately. *Protective self-presentation* (PSP) refers to the avoidance of social rejection, i.e. a protective self-presenter fears social disapproval if he/she does not manage to behave appropriately in a social situation.

We believe that people are interested in self-presentation in general. We thus suppose that individuals present themselves in a more positive light when their behavior is identifiable by others. Consequently, we expect the highest contribution rate to occur in the individual-feedback condition:

A main effect for activity awareness with respect to participants' cooperation rate is hypothesized (H1).

In addition, it is supposed that high protective self-presenters are more cooperative than low protective self-presenters, when activity awareness allows for the identification of individual behavior and consequently for self-presentation. Where such activity awareness is lacking, high and low protective self-presenters are assumed to be equally cooperative:

An interaction effect of PSP and activity awareness with respect to cooperation rate is hypothesized (H2).

Method

Participants

119 university students participated in the study (70 women and 49 men, mean age = 24.3 years). They were informed that they would be participating in a group study using computers. Participants were randomly assigned to one of the three conditions with 43 participants in the control condition, 37 in the group-feedback condition, and 39 in the individual-feedback condition.

Procedure

Participants were led to believe that they would be one of six persons working in a group that is distributed across six locations and that is connected via a database. In fact, participants worked independently of the others: the behavior of the other participants was simulated using software. The participants' task entailed the calculation of fictitious salespersons' salaries (cf. Cress, 2005). In a first phase, participants were required to calculate the *base salaries* of as many salespersons as possible. In a second phase, the *total salaries* were to be calculated. Participants received money according to the number of base and total salaries calculated. Following the calculation of a base salary, participants had to decide whether to share their result with the other group members by contributing it to the shared database. When contributing a base salary, the respective participant had to wait for the somewhat lengthy transfer of the result to the database. During this waiting time, he/she was not able to continue with further calculations. Hence, each participant could calculate and consequently earn more, the less base salaries she/he contributed to the database. In the second phase, participants received money for each total salary calculated. In calculating a total salary participants required the appropriate base salary. If this base salary was not available (i.e. it was neither in the database nor had it been calculated by the participant in the first phase), the participant had to catch up on this calculation in the second phase. This resulted in a loss of time in which the participant was not able to earn money. Each person therefore earned less, the less pieces of information in the database. Hence, participants found themselves in a characteristic information-exchange dilemma: an individual earned less, the more information he/she shared with others, and at the same time, everybody earned more, the more pieces of information were available in the database. The succession of phase 1 and 2 was repeated three times. Except for the control condition, awareness information was presented by an awareness tool after each of the three trials. The different experimental conditions are presented in the following.

Conditions

Three experimental conditions were realized in this study:

- a *control* condition without feedback.
- a *group-feedback* condition in which an awareness tool presented the average contribution behavior of the other five group members and the participant's own contribution behavior in the first phase of the preceding trial (cf. Figure 1).
- an *individual-feedback* condition in which an awareness tool separately provided the contribution behavior of each group member in the first phase of the preceding trial (cf. Figure 2).

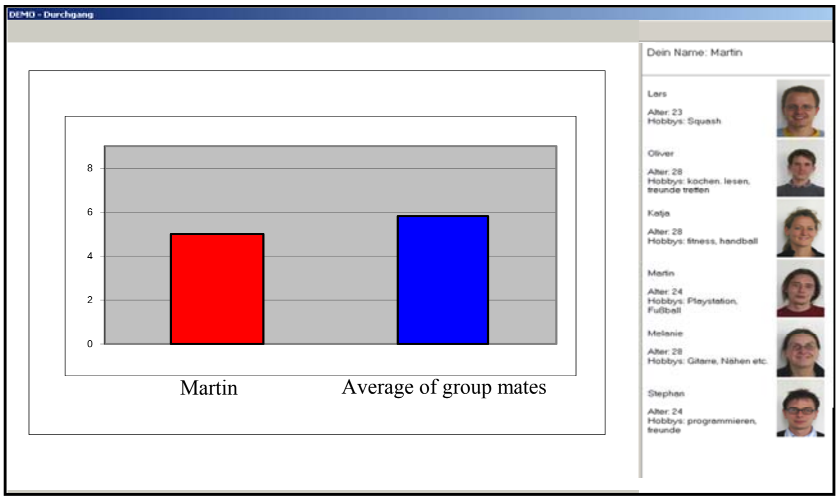

Figure 1. The group-feedback condition with "Martin" as relevant participant.

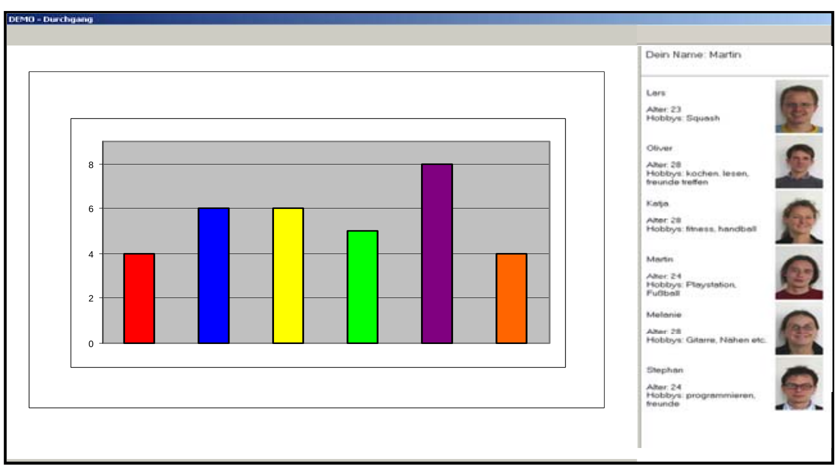

Figure 2. The individual-feedback condition enabling identification of each participant's behavior.

In both feedback conditions, the contribution behavior of cooperative group members was presented on the basis of the same pool of data. Photographs of the team members were provided in all conditions in order to foster social awareness.

Measures

A German version of the self-presentation scale according to Wolfe et al. (1986) was employed. This scale consists of two subscales (Laux & Renner, 2002): "acquisitive self-presentation" and "protective self-presentation". The subscale "acquisitive self-presentation" was excluded based on considerations that the individual-feedback condition – as operationalized here – is socially too reduced to allow for social profits such as making new friends. The subscale "protective self-presentation" on the other hand, was considered relevant for the present research question, given the adequate situational authenticity, whereby individuals sensitive to such processes could indeed experience social disapproval. The PSP-subscale consisted of twelve items. All items were rated on a 4-point scale with endpoints labeled 1 (*not at all*) and 4 (*very*).

Results

The employed scale showed satisfactory internal consistency. Cronbach's alpha for PSP was α=.83. With respect to PSP, participants were separated into two groups via a median split (cf. MacCallum, Zhang, Preacher, & Rucker, 2002). Cooperation rate was defined as the quotient of contributed and totally calculated base salaries. This quotient in the second and third trial served as the main dependent variable (the first trial was excluded because feedback was provided for the first time *after* the first trial).

Test of Hypotheses

In order to test both hypotheses, an ANOVA with PSP and group awareness as independent variables was calculated. A marginally significant main effect of group awareness with respect to cooperation rate (H1), $F(2, 113)=2.63$, $p=.076$ was yielded. Post-hoc tests (Scheffé) showed that only the control condition and the individual-feedback condition differed significantly from each other: $M_{cc}=.54$ ($SD=.35$) vs. $M_{ifc}=.69$ ($SD=.28$). The group-feedback condition lay between the two: $M_{gfc}=.56$ ($SD=.32$).

The ANOVA also showed a significant interaction effect for PSP and group awareness (H2), $F(2, 113)=4.28$, $p=.016$. Figure 3 illustrates this effect.

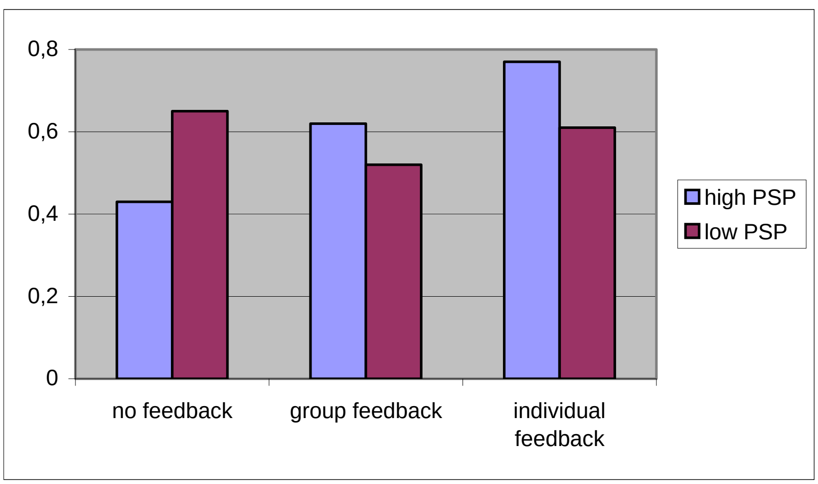

Figure 3. Cooperation rates for the three conditions according to PSP (low vs. high protective self-presenters).

As expected, there was no difference between high and low protective self-presenters in the group-feedback condition: $M_{low}=.52$ ($SD=.33$) vs. $M_{high}=.62$ ($SD=.32$), $p>.05$, but a significant difference in the individual-feedback condition: $M_{low}=.61$ ($SD=.30$) vs. $M_{high}=.77$ ($SD=.24$), $p<.05$. However, an unexpected difference was also found in the control condition: $M_{low}=.65$ ($SD=.33$) vs. $M_{high}=.43$ ($SD=.34$), $p<.05$.

Single Items Analyses

In order to better understand the way in which the need for PSP influences people's willingness to share their knowledge, it is worthwhile taking a closer look at those items which were more exactly able to predict the protective self-presenters' selective contribution behavior. We found three items showing the same interaction effect with group awareness as the total twelve-item scale. In the following list, these items are presented with their exact wordings (own translations from German) and corresponding statistics resulting from ANOVAs with the PSP-items and group awareness as dependent variables:

1. "If all persons of a group act in a certain manner, then I feel that this must be the appropriate way to behave." The ANOVA yielded an interaction effect with respect to cooperation rate, $F(2, 113)=6.03$, $p=.003$.
2. "The slightest hint of disapproval in the eyes of another person is sufficient to make me change my behavior." The ANOVA yielded an interaction effect with respect to cooperation rate, $F(2, 113)=4.73$, $p=.011$.
3. "It is important for me to fit into the group to which I belong." The ANOVA yielded an interaction effect with respect to cooperation rate, $F(2, 113)=3.54$, $p=.032$.

That which these three items have in common is that they all loaded onto the same factor resulting from a main component analysis of the twelve PSP-items with quartimax rotation. This procedure revealed three factors.

- The first factor had an eigenvalue of 4.30 and accounted for 35.8% of the explained variance. With regard to content and in accordance with Laux and Renner (2002), we labeled this factor "protective variability".
- The second factor had an eigenvalue of 1.93 and accounted for 16.1% of the explained variance. With regard to content, we labeled this factor "fear of social disapproval".
- The third factor had an eigenvalue of 1.06 and accounted for 8.9% of the explained variance. With regard to content and in accordance with Laux and Renner (2002), we labeled this factor "protective social comparison".

The three items showing an interaction effect with group awareness all loaded onto the factor "fear of social disapproval".

Discussion

The individual's motivation to share her/his knowledge with other persons is an essential precondition for successful CSCL (Stahl, Koschmann, & Suthers, 2006). A central reason for people's poor willingness to share their knowledge can be found in the viewpoint that computer-supported knowledge exchange represents a social dilemma. The present article studied the role of group awareness and self-presentation within this information-exchange dilemma. On the one hand, the study entailed the examination of three different group-awareness conditions in a dilemma situation. On the other hand, the personality variable of protective self-presentation was investigated. The study thus takes an explicitly interactional perspective, i.e. it examines situational and personal determinants of behavior as well as their interactions within an information-exchange dilemma. The construct of PSP as a personality variable is employed as an auxiliary means, insofar as knowledge concerning individuals' characteristics can help provide information about the situation in which these people exhibit a certain behavior. In doing so one can learn more about the effectiveness of group awareness. To this end, we observed the way in which persons with high and low scores in PSP reacted to the group-awareness information provided. Based on observations of ensuing behavioral reactions, conclusions can be drawn regarding the effect of group awareness which is generated by a respective tool.

Persons receiving individual feedback on cooperative group mates clearly increase their cooperation rate in comparison to those receiving no feedback. The result showing that group feedback failed to increase cooperation rates suggests that – at least in the study reported here – mere feedback on cooperative group mates in itself does not necessarily enhance the willingness to share one's knowledge. Rather, in addition to this perception of cooperativeness and the resulting trust in others in the information-exchange dilemma (Kimmerle, Cress, & Hesse, 2006), self-presentation opportunities should be made available.

The interaction effect found for feedback and PSP shows that persons with a high need for PSP are particularly cooperative in the individual-feedback condition. However, without feedback allowing for identifiability, it is this very subgroup, that proves particularly selfish in demonstrating a low willingness to share knowledge. Two insights can be gained from this finding. Firstly, we learned how group awareness can be affected by individual feedback: a situation in which the behavior of every single person concerned can be exactly identified is used by the participants in the information-exchange dilemma for purposes of self-presentation. Secondly, important insights can be gained concerning the psychology of individuals with a high need for PSP: even though this result cannot be generalized beyond the current CMC setting, it can be concluded that high protective self-presenters do not simply try to present themselves in a positive manner when their activities are recognizable to others, but that they are also especially uncooperative when this is not the case.

Taking a closer look at those individual items showing the same interaction effects with the group-awareness condition as the total PSP-scale, can facilitate a more detailed understanding of high protective self-presenters' contribution behavior. In its entirety, the PSP construct is composed of three facets: "protective variability", "fear of social disapproval", and "protective social comparison". The fact that the individual items concerned all load onto the factor "fear of social disapproval" suggests that contribution behavior is caused merely by people's dread of being negatively evaluated by their peers. However, this can in our opinion only explain why high protective self-presenters enhance their cooperation rate when their behavior is identifiable. It cannot, however, explain why these very individuals decrease their cooperation rate in an anonymous situation. Further research is required to examine this issue in greater detail.

While underlying processes of information exchange were not uncovered in their entirety, it can be concluded that the approach adopted in the present article – gaining new insights by capturing interactions of personal and situational aspects – proved fruitful. This approach could help researchers gain new insights concerning the effects of group awareness and the influence of PSP as a personality variable. It is therefore our view that such an interactional perspective can also be recommended for research in other issues of CMC and CSCL.

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Demonstration of a Discussion Terminal for Knowledge Acquisition and Opinion Formation in Science Museums

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Abstract: There is a trend for active visitor engagement at science museums: Visitors' opinions about science topics are often integrated into exhibitions, today. Modern discussion-based installations are described in this paper. In particular, we present a computer-mediated discussion terminal which was designed to mediate and encourage elaboration on and opinion exchange about the topic nanotechnology as one of the most explosive science topics nowadays. It is supposed to foster critical thinking, knowledge acquisition, and opinion formation at science museums. The rationale behind and assumptions about the impact of this discussion terminal are explicated.

Science Museums and Public Understanding of Science

Oppenheimer has already stated 1968 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 increasing. Informal learning in science museums can be a major contributor in promoting public understanding of science as museums are one central medium in communicating scientific ideas and presenting relevant objects (Durant, 1992). In addressing current socio-scientific issues science museums are challenged to present the ambiguity and controversy of these topics and to support visitors in developing reflective and critical thinking. Boyd (1998, p. 214) considers the modern science museum as a "marketplace of multiple points of view, a forum where controversy can be aired". However, museums might not only provide information about competing viewpoints and sources but also place visitors into the centre of the debate by giving them an own voice: Cameron (2003, p. 21) states that "the key issue in the reformation of museums is the audience participation in debates". Thus, museums face the challenge to develop new installations which emphasize visitors' involvement, challenge their views, and foster opinion formation about current scientific issues.

Modern Discussion-Based Installations for Active Visitor Engagement

The idea to collect visitors' impressions about an exhibition and its content is not new: Guest books are common practice to provide space for personal opinions. However, modern technologies offer new opportunities to integrate these personal opinions into an exhibition and to engage visitors in discussion and debate about presented issues. Some interesting new installations have been developed in the last years which provide "talk-back" areas where visitors can express their feelings or opinions about the exhibition and find out what other people think. At Deutsches Museum (Munich, Germany), an asynchronous discussion terminal was implemented into an exhibition about stem cell research where visitors could listen to various expert statements, type an own statement into the forum, and read through others' statements (cp. fig. 1a). Visitor research showed that this terminal was used quite intensively but also identified a lack of quality of visitors' statements. This field observation hints to the need for research how to explicitly support elaboration on relevant information to raise quality of opinion expression.

Figure 1 shows design proposals (© Kaiser Matthies, Berlin) for a new exhibition about nanotechnology (NT) at Deutsches Museum. Visitors' personal visions about their future life with nanotechnological applications and their opinion about chances and risks will be video-recorded and integrated into the exhibition as "nano visions". Other visitors can view various videos and learn about others' opinion about NT and its implications for daily life. Figure 1b shows a discussion area which was designed to gather visitors' personal statements and votings with regard to concrete controversial questions. These votings will be aggregated and displayed on large screens to provide an overall feedback about all visitors' opinions (cp. fig. 1b). Similarly, the London Science Museum projects controversial questions on a large table and visitors can vote by pressing the buttons 'yes' or 'no' (cp. fig. 1d). The displayed results might then serve as a starting point for f2f-discussion. Such installations follow the current trend to personalize exhibition context, to evoke emotions, to actively involve museum visitors, and promote critical and reflective thinking at science museums (Pedretti, 2006). The question whether museums really accomplish this will be addressed in our research about the potential of discussion terminals at science museums.

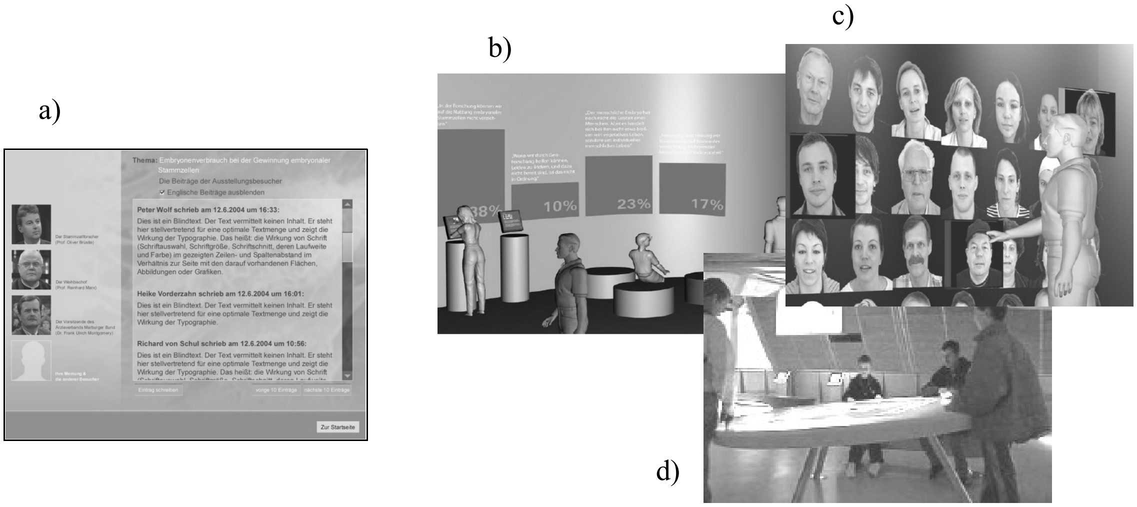

Figure 1: Examples for new discussion-based installations
(Deutsches Museum, Munich, Germany, 1a - 1c; London Science Museum, 1d)

A Discussion Terminal Informed by (Socio-) Cognitive Theories

The idea of scaffolding systematic and deep processing of relevant information about risks and potentials of NT and thereby enhance critical thinking and opinion formation of museum visitors is central to our research: A discussion terminal has been designed 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. The discussion terminal will be integrated into an exhibition about NT, and visitors have the opportunity to elaborate on relevant information and write down their own opinion about NT, and read through others' statements. Furthermore, they will get specific feedback on others' opinion about NT.

Different types of cognitive mechanisms are assumed to lead to deeper elaboration of content and belief-based opinion formation when visitors interact with the discussion terminal:

1. *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).
2. *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 (Rosenberg, 1956). Expert statements might be presented as these are necessary information about NT required for critical evaluation of this new technology. To support critical thinking, these expert statements could be rated by visitors with regard to agreement and relevance (cp. figure 2a). This should help to identify relevant attributes of NT and should therefore scaffold belief-based, thoughtful opinion formation. Alternatively - and probably more adequate for the museum context - one could imagine a game-based activity like a drag and drop-quiz where visitors have to assign the experts to their statements (cp. figure 2b).
3. *Social comparison information and opinion exchange.* Social influences are important for individual opinion formation and information processing as according to social comparison theory people tend to evaluate their own opinion by using similar others as models (Suls, Martin, & Wheeler, 2004). The discussion terminal offers new possibilities to support communication and debate between visitors - independent from their time of visit. Therefore, this research project considers the impact of reported opinions of other visitors on individual cognition. An awareness tool is used that summarizes others' opinions and displays one's own opinion in comparison to others'. In addition to this specific social comparison information, all individual statements can be accessed, too. Congruent feedback might increase visitors' confidence in their opinion. Conflicting feedback elicits a cognitive conflict or makes it salient. This conflict should elicit further activities at the discussion terminal and within the exhibition (Buchs, Butera, Mugny, & Darnon, 2004; Lowry & Johnson, 1981). Visitors might, for example, read through others' statements to learn about their arguments, too ("Why do they think that?").

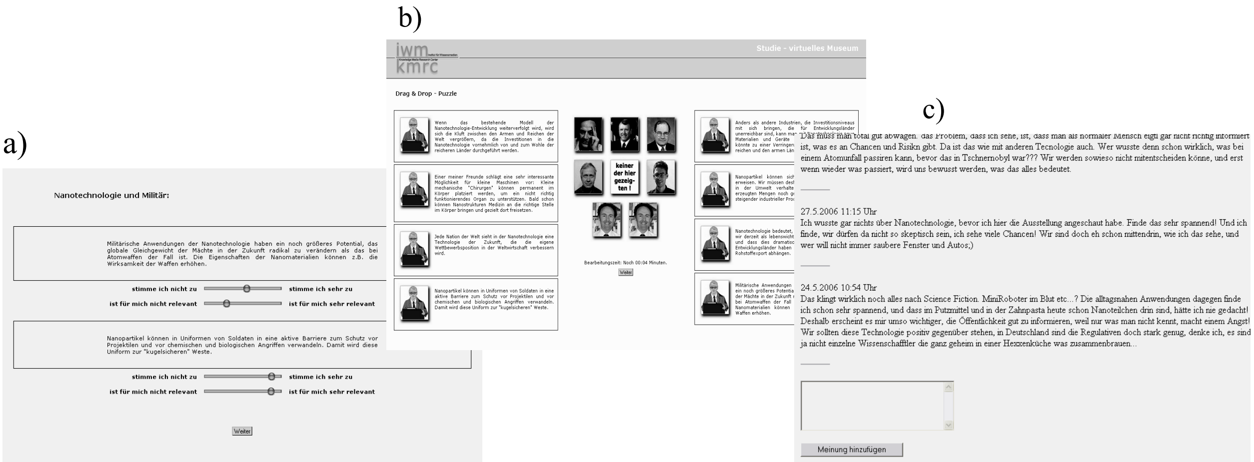

Figure 2: A discussion terminal for knowledge acquisition and opinion formation at science museums

Impact of a Discussion Terminal on Knowledge Acquisition and Opinion Formation

It is assumed that salience of controversial arguments, possibility to express one's own opinion, and social comparison information are all crucial factors for both learning and opinion formation. Elaboration on information should be deeper when these factors are implemented. Visitors should gain most (attitude-relevant) knowledge, remember more relevant arguments and have more sophisticated opinions about NT if the discussion terminal presents relevant information and gives the opportunity to write down one's own opinion. Salience of arguments might support acquisition of attitude relevant knowledge as relevant information is presented at the discussion terminal. Belief-based opinion formation on basis of presented arguments should be more likely which would result in more adequate and sound-standing attitudes towards NT. 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. An experimental study was developed to test these assumptions.

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Are core objectives of web-based collaborative inquiry learning already core learning prerequisites? The case of argumentation competences and computer literacy

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Abstract: We investigated whether argumentation competence and computer literacy, which are typically regarded as goals of web-based collaborative inquiry learning, also constitute important learning prerequisites for the acquisition of domain-specific knowledge. Results of two empirical studies showed that learners with higher argumentation competence and learners with lower computer literacy acquired more domain-specific knowledge. Core objectives of collaborative inquiry learning can be influential prerequisites as well, albeit not always in the way that may be expected.

Collaborative inquiry learning is recognized as a powerful way to enable students to acquire scientific concepts. It requires them to conduct activities similar to those of scientists. From a socio-cultural perspective, it is expected that, through their participation in scientific activities, students develop domain-general competences such as argumentation competence. One further advantage of web-based collaborative inquiry learning environments is that they may foster students' computer literacy. In two studies we investigated to what extent these two domain-general competences also constitute important learning prerequisites for domain-specific knowledge acquisition.

Study 1: Argumentation in inquiry learning – prerequisite and outcome?

Argumentation competence comprises the ability to understand and produce sophisticated single arguments and argument sequences. According to Toulmin's (1958) argument scheme or simplified variants of it, sophisticated single arguments have certain structural components such as claims, data and reasons. According to the model of Leitão (2000), an argumentation sequence particularly beneficial for collaborative learning should consist of argument, counterargument, and integration. We subsume these aspects of argumentation competence under the concept of "internal scripts on collaborative argumentation". Schank (1999) viewed scripts as individual memory structures that guide individuals in acting in and understanding specific situations. In terms of the structural and the sequential model of argumentation, individuals with high structured *internal scripts on collaborative argumentation* should be more capable of constructing arguments containing data, claims, and reasons as well as in producing counterarguments and integrative arguments than individuals with low structured internal scripts. As inquiry learning as strongly requires learners to engage in collaborative argumentation, our hypothesis for study 1 was that learners exhibiting a high structured internal script on collaboration argumentation prior to the inquiry learning session will acquire more domain-specific knowledge than learners exhibiting low structured internal scripts.

Method

Participants and Design. Participants in this study were 46 students from grades 8 to 10 from secondary schools. We compared two conditions from a larger study (Kollar, Fischer & Slotta, 2005) with students with a high vs. low *degree of structuredness of their internal scripts on collaborative argumentation*. The degree of structuredness of the internal scripts was assessed by a test based on simplified Toulmin and Leitão models of argumentation (Cronbach's α = .61). Using a median-split, we identified 24 learners with a high structured internal script and 22 learners with a low structured internal script on collaborative argumentation. Participants in each of the two groups were coupled homogeneously with respect to gender and to their internal scripts' degrees of structuredness.

Procedure. In a first session of about 45 minutes, learners were asked to complete several questionnaires for their domain-specific prior knowledge and the degree of structuredness of their internal scripts. In the second session (two weeks later) the learners received a short technical introduction, collaborated in dyads for 120 minutes on a German version of the unit "The Deformed Frogs Mystery" from the WISE environment. There, the learners faced two competing hypotheses explaining why so many frogs were deformed in the nineties in the U. S. Their task was to discuss the two hypotheses against the background of evidence presented in the environment. On several occasions, they were asked to discuss the two hypotheses against the background of the information they just had reviewed and to type their ideas into a text box. Finally they individually completed a post-test,for their domain-specific knowledge. Each dyad shared one computer.

Instruments. *Processes of collaborative argumentation* were analyzed based on ten samples of five minutes from each transcription of the dialogues during the inquiry unit. Transcriptions were first coded for the occurrence of argumentative or non-argumentative talk (Cohen's $\kappa = .78$). Then two coders independently from each other identified single arguments. Each argument was rated for its structure as low, medium, or high (Cohen's $\kappa = .68$). The *outcomes of collaborative argumentation* were assessed by the same test for domain-specific knowledge before and after collaboration. It included five open-ended questions about mechanisms assumed in the two hypotheses, empirical evidence, and plans concerning how to decide what caused the deformities (Cronbach's $\alpha = .58$).

Results

On the *process* level, dyads with high structured internal scripts produced more arguments than dyads with low structured internal scripts ($t(11.33) = 3.32$; $p < .01$). Learners with high structured internal scripts produced more arguments with medium ($t(14.42) = 3.32$: $p < .01$) and high ($t(15.57) = 3.41$; $p < .01$) levels of structure than learners with low structured internal scripts, but about the same amount of arguments with low structure ($t(20) = 0.60$; *n.s.*). On the *outcome* level, learners with high structured internal scripts outperformed learners with low structured internal scripts on the post-test for domain-specific knowledge ($F(1,43) = 4.64$, $p < .05$, $Eta^2 = .10$).

Study 2: Computer literacy in web-based inquiry – prerequisite and outcome?

According to assumptions about a so-called "second-level digital divide", people's computer literacy may affect their chances to acquire knowledge from digital media (Hargittai, 2002). In this study, we focuss on familiarity with computers as one aspect of computer literacy (Richter, Naumann, & Groeben, 2001). Typically, web-based inquiry learning environments require learners to engage in two types of media-related activities. On the one hand, learners are required to engage in active processing of *media elements for receptive use*, such as text, pictures or films. On the other hand, they are often provided with the opportunity to actively manipulate *media elements for productive use*, such as the so-called SenseMaker in many WISE environments, in which students can sort evidence according to the claim it supports by drag-and-drop manipulation. To benefit from such elements, learners need to have actively processed the content of elements for receptive use in which the evidence is presented (Kintsch, 1998). As it can be expected that students with a high level of computer literacy exhibit a more effective pattern of media use in a sense that they are more capable in adopting adequate strategies for both the receptive and the productive use of media elements, our hypothesis for study 2 was: Learners with higher computer literacy will acquire more domain-specific knowledge than learners with lower computer literacy.

Method

Participants and Design. The participants were 37 students from a secondary school; 15 fulfilled the criteria for inclusion in the analysis. The design compared students with high vs. low *computer literacy*. This was assessed by a seven items (Cronbach's $\alpha = .83$) adaptation of the subscale "familiarity with computers" from the German computer literacy inventory (INCOBI; Richter et al., 2001). The median of 0.43 was used for a split. 8 participants had high and 7 had low computer literacy. Dyads were homogeneous in gender, but not computer literacy.

Procedure. On the first day, learners filled in several questionnaires, including tests of prior domain-specific knowledge and familiarity with computers. Then they received an introduction to the learning environment, and collaborated in dyads on a German version of the WISE unit "How far does light go". Again, they faced two competing hypotheses they were supposed to discuss against the background of evidence presented in the learning environment. For example, they could view pages with text, pictures and films (media elements for receptive use), and use notepad windows and the SenseMaker tool to document their findings (media element for productive use). On the second day, dyads continued collaboration and finally completed a post test for domain-specific knowledge. Again, each dyad shared one computer

Instruments. The main dependent variable was the learners' *domain-specific knowledge* gains from pre- to post-test, as measured by an adapted version of a test specific for this unit (Cronbach's $\alpha = .77$ in the post-test). We analyzed the *patterns of media use* by coding segments (10sec each) from screen recordings of the learning processes with respect to the media element displayed (receptive, productive, or other; Cohen's $\kappa = .75$).

Results

With respesct to *domain-specific knowledge* we found an unexpected result: Learners with high computer literacy had higher domain-specific knowledge gains than learners low computer literacy ($t(13) = 2.60$, $p < .05$). Correspondingly, we observed a substantial negative correlation between computer literacy and knowledge gains ($r = -.54$, $p < .05$). To explain this surprising finding, we analyzed the *patterns of media use* on a single case basis. In one prototypical dyad with high computer literacy, we observed a tendency to quickly rush through the environment and to focus mainly on media elements for productive use. In contrast, in a prototypical dyad with low computer literacy, the students proceeded at a lower pace, often going back and forth between media elements for re-discussion. This may indicate that they elaborated the material more deeply than the first dyad, which might be an important precondition to successfully interact with media elements for productive use. They also distributed their attention over media elements for receptive and productive use more evenly (Wecker, Kohnle & Fischer, in press).

General discussion

The two studies show that argumentation competence and computer literacy, which both can be regarded as core learning objectives of web-based collaborative inquiry learning environments, also play a role as individual learning prerequisites for domain-specific knowledge acquisition. Both domain-general competences were found to influence the amount of domain-specific knowledge acquired by the students. Learners with less sophisticated argumentation competences may be disadvantaged with this learning approach without further instruction. However, higher competence levels do not always guarantee higher learning gains: Higher computer literacy may be associated with worse outcomes in terms of domain-specific knowledge acquisition lower computer literacy. Our analysis of the patterns of media use reveals possible explanations for this surprising finding. It appears that learners with a high level of computer literacy may easily transfer their usual web-browsing behaviour to web-based collaborative inquiry learning environments, in which a more profound elaboration of information would be necessary. Additionally, they seem to be attracted a lot by media elements that afford active manipulation, but often use them without deep elaboration of the learning material. – From our perspective, these results lead to at least three important consequences. First, theory-building on inquiry learning should focus more on individual learner characteristics that may influence the success of inquiry learning. Second, designers should try to explore ways how to design web-based collaborative inquiry learning environments that accommodate learners with a variety of individual competence profiles based on online-assessments of individual competences. Third, teachers need to find out about their students' competence profiles and to decide for which inquiry activities they need support. To guide teachers in this challenging task, we need theoretical accounts and aligned empirical research on the question how individual learning prerequisites, the use of digital media, and teaching behaviors must be "orchestrated" (Fischer & Dillenbourg, 2006) in order to accommodate heterogeneity among students.

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Fostering argumentation with script and content scheme in videoconferencing

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Abstract: This study examines the support of argumentation in collaborative task solving in videoconferencing. In particular, it investigates the effects of a script (which supported the collaboration) and a content scheme (which fostered the focusing on the content) on transactivity in argumentation and on justifications of single arguments in the learning discourse and task solutions. Learners were asked to learn a theory individually before working on a task cooperatively. Altogether, 52 triads were randomly assigned to one of four conditions in a 2 (with/without script) x 2 (with/without content scheme)-factorial design. To measure the effects of the intervention, the argumentation in the learning discourse and in the task solutions was analyzed. Results show no effects of the script on transactive reactions, but small effects of the content scheme. The content scheme also influenced the construction of arguments with justifications positively. Justifications in task solutions were supported by script and content scheme.

Introduction

Argumentation is an important ability in everyday life and scientific work. To justify a point of view, to compare different opinions and thus achieve an integration or arrive at a conclusion is a main antecedent for deciding on difficult tasks. Argumentation is defined as "a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader, by putting forward a constellation of propositions intended to justify (or refute) the standpoint before a rational judge" (Van Eemeren, Grootendorst, & Henkemans, 1996, p. 5). In scientific discourse, argumentation is a very important ability for establishing diverse perspectives in collaborative task-solving by confronting cognitions and their foundations (Andriessen, Baker, & Suthers, 2003). These perspectives comprise different knowledge, information or points of view which are necessary for solving an interdependent task collaboratively (Jonassen, 2000). In this collaborative discourse, argumentative activities are necessary. These imply that group members have to disseminate their different points of view on the task, that they exchange their knowledge about it and discuss task-relevant aspects.

Argumentation in collaboration

Regarding argumentation in collaboration, there are especially two aspects relevant: transactive reactions and justifications in single arguments. These are explained in the following two chapters.

Transactive reactions in argumentation

Looking at argumentation as discursive exchange of different opinions between collaborating partners more closely (Leitao, 2001), it is important how collaborating partners react to each other argumentatively in joint task-solving. In argumentation, one action and three reactions are important (Leitao, 2000): Statements as action, and confirmations, counter-arguments and replies as reactions. The reactions can follow on statements, but also on other reactions. The processes behind these action and reactions are the following. In the first step, people have to elaborate their own point of view to start argumentation in collaboration (statements). Secondly, the collaborating partners have to cognitively process the explanations and elaborations they heard, compare them with their own point of view and draw a conclusion concerning their reaction on it. This could for example be a confirmation and a counter-argument. Confirmations show the agreement with a point of view, while counter-arguments express a different point of view (Leitao, 2000; 2001). The third kind of reaction includes a reply (Leitao, 2000), which could be an integration of different points of view, an evaluation or conclusion of the argumentation. The activities behind replies are based on comparing and evaluating the different points of view and on drawing a conclusion concerning the most adequate argumentation. Argumentative action and reactions can permanently alternate due to the dynamic in collaboration. Regarding reactions in argumentation, there are particularly two kinds of reactions possible: one in which collaborating partners refer their utterance to a previous assertion of another member of the group and one in which they do not relate their opinion to former statements. The first reaction is classified as transactive. A reaction is "considered transactive when it extends paraphrases, refines, completes, or critiques the partner's reasoning or the speaker's own reasoning" (Teasley, 1997, p. 362). Transactivity is one important characteristic of argumentation because by relating utterances to other people, the discussants' cognitive processing is shown.

Research in the field of argumentation regarding transactivity was investigated by Leitao (2000). In a study with two real groups, she qualitatively analyzed the argumentative discourse concerning the validity of argumentation and the kind of argumentative reactions of group members according to the categories statement, confirmation, counterargument and reply. Results showed that the discussants modified or specified their opinions during argumentation, but did not give them up in favor of a counter-argument. Other studies focused on transactive reactions in a quantitative way. In a study by Berkowitz and Gibbs (1983), individuals who reacted more frequently in a transactive way to each other during discussion changed their moral points of view more often, too. Thus, transactive reactions may evoke deeper cognitive processes of elaboration and reflection, so that individuals improve their own argumentation. Therefore, it is important to analyze these elements of argumentation during collaboration.

Regarding such discourse elements in argumentation, for many people it is difficult to formulate statements, to confirm and refuse them (Kuhn, Weinstock, & Flaton, 1994) or to reply in an integrative or deductive way with the aim of solving a task collaboratively. First, people often do not elaborate and justify their points of view so that their collaborating partners are able to understand their arguments. Second, the reaction to these statements requires complex processes of comparing one's own opinion with the uttered opinion. And third, coming to an integration or conclusion due to an evaluation process of all different points of view necessitates meta-cognitive abilities, which are difficult to perform (Dansereau, 1988). Therefore, people need support in their argumentative collaboration. One possible method comprises the structuring of this collaboration.

Justifications in argumentation

Apart from transactivity, a second aspect concerning argumentation refers to the justifications of single arguments. Referring to logical reasoning, arguments comprise two components: premises and conclusions (Fisher, 1988). In this context Kuhn (1991) defines arguments as "assertions with accompanying justification" (p. 12). Therefore, an argument is a meaningful expression to support another utterance (Andriessen et al., 2003). Justifying points of view is a main antecedent for convincing collaborating partners of the correctness and adequacy of arguments. In collaboration, learners not only have to take their own reasoning into consideration, but also the externalized statements of their collaborating partners. Therefore, learners not only have to reflect on their own argumentation, but also on their collaborating partners' argumentation. The antecedent for correct justifications in arguments is the concentration on adequate and relevant content. A main problem in this context concerns the fact that people often do not justify their points of view at all, but simply put forward claims and hypotheses (Kuhn, 1991). In scientific task solutions, theory and evidence must both be considered and related to each other (Kuhn, Schauble, & Garcia-Mila, 1992). Focusing on these two aspects is very challenging for learners. Furthermore, if learners do not know which content they should stress, they will not be able to justify their arguments in the intended direction. In this context it is helpful to support learners focusing on the content.

To sum it up, many studies show that people often do not argue in collaboration in an adequate and logical way. For collaborating partners exchanging arguments transactively in collaboration and constructing logical arguments with justifications is often difficult and it is due to the lack of such abilities that support is necessary.

Fostering collaborative argumentation in videoconferencing

In settings of computer-based learning argumentation can be fostered by the design of learning environments. In concrete terms this means that the computer is used as external knowledge representation which could be structured in such a way that argumentation is fostered (Andriessen, et al., 2003). In this contribution, we focus on indirect support methods fostering the interaction and discussion of collaborating partners and thus also argumentation only implicitly (Van Bruggen, & Kirschner, 2003). These methods rely on the computer as external knowledge representation tool. In computer-mediated communication, learners mostly have to solve a task together by using the computer for externalizing their knowledge and for recording their task solution which implicitly influences argumentation both in transactive argumentation and in justifications of arguments. In respect to transactive argumentation, the representational tools can have two effects: First, the explication of different points of view is initiated (Munneke, Van Amelsvoort, & Andriessen, 2003). Secondly, by representing ideas and different perspectives on the task in a shared way, the joint representation may function as external group memory that allows learners to refer to previous ideas (Van Bruggen, Boshuizen, & Kirschner, 2002). These references express transactive reactions. Concerning the justifications of arguments, the external representations activate processes of identifying components of arguments and of evaluating their consistency, accuracy or plausibility (Munneke, et al., 2003) which can improve the externalized knowledge.

Beyond these effects of representational tools for argumentation per se, there are further indirect instructional support methods for fostering transactive argumentation and the justifications of arguments, namely scripts and content schemes. These do not concentrate on the enhancement of argumentation directly, but are focused on strategic and content-specific aspects of the task collaboration. Strategic support could be realized by *scripts*. These structure the collaboration process itself with a pre-defined procedure, in which every step of the collaboration process itself is prescribed with sub-tasks. There are a lot of different definitions and application scenarios concerning scripts (Kollar, Fischer, & Hesse, in press). The term, usually taken from cognitive psychology (Schank, & Abelson, 1977), is increasingly used in CSCL learning environments as instructional support method (see Fischer, Kollar, Mandl, & Haake, 2007). In this context, scripts mainly sequence collaboration and assign specific activities to the learners (Ertl, Kopp, & Mandl, 2007).

In videoconferencing, scripts focus on the assignment of specific tasks to foster the application of collaboration strategies. These tasks aim at the learners exchanging information, replicating important information and reflecting about the relevance of the tasks for their collaborative task solution (Reiserer, 2003). Two videoconferencing studies show a positive effect of the script intervention on the learning discourse (Härder, 2004; Reiserer, 2003). Yet, it is not investigated whether this effect also concerns transactive reactions in argumentation during the collaboration process, the justifcations of arguments, and the justification of collaborative and individual task solutions. As scripts foster the exchange of information as well as the discussion and reflection on it, they can also have an influence on transactive reactions in argumentation. Furthermore, focusing on information exchange may also effect that relevant information is used for justifying task solutions.

Content schemes represent and pre-structure the key concepts of a certain domain (Brooks, & Dansereau, 1983). This means that important content-specific components are labeled on a meta-level to focus learners on aspects which are relevant for the collaborative task solution. In CSCL learning environments, these content schemes are realized by pre-structuring the computer which is used as external representation. Potential realizations include tables (Reiserer, Ertl, & Mandl, 2002), matrices (Suthers, & Hundhausen, 2001) and maps (Fischer, Bruhn, Gräsel, & Mandl, 2002). The underlying assumption behind the support with content schemes is based on the theory that the visualization of main task-relevant aspects increases the learners' awareness of the content they are to focus on. In this context, the concept of 'representational guidance' is of importance (Suthers, 2003; Suthers, & Hundhausen, 2003) which refers to the salience of the task: Because the content scheme keeps the task-relevant components permanently salient, learners rely and focus on them.

Studies in videoconferencing scenarios often showed a beneficial effect of the content scheme on the collaboration discourse (Fischer, Bruhn, Gräsel, & Mandl, 2000; Reiserer, Ertl, & Mandl, 2002). However, it has not yet been investigated, whether the content scheme can foster argumentation and if so whether this effect then also shows in the collaborative and individual task solution. As content schemes stress main components of the task solution, they may influence argumentation in a way that different statements and counter-arguments are disseminated. In addition to this, making important aspects of the task salient may improve the justifications of arguments, which could become manifest not only in the learning discourse itself, but also in more justifications during the collaborative and individual task solution.

Although script and content scheme give first hints of beneficially influencing collaborative activities, it has to be asked whether the instructional support helps learners to justify their *task solution* more adequately. In this context, the collaborative and the individual task solution is relevant (Salomon, 1992). There are only few studies which focused on this aspect. For example Weinberger, Segmann, Fischer, and Mandl (2007) only found an effect of their script on the individual knowledge about argumentation sequences and about the structure of arguments, but not on the collaborative and individual task solution. Furthermore, there was no effect of scripts on the collaborative task solution either in a study by Baker and Lund (1997). The content scheme had also no clear effect on the collaborative task solution in a discussion (Kanselaar, Erkens, Andriessen, Veerman, & Jaspers, 2003; Suthers, 2003). Only the SenseMaker had a positive influence on the learners' individual concept of light (Bell, 1997; 2002). There are no clear effects of instructional support methods on task solutions. On top of this, there is no evident effect that the frequency of mentioning certain topics manifests itself in the collaborative task solution. For example, in a study by Andriessen, Erkens, Van de Laak, Peters, and Coirier (2003), learners who discussed a topic more frequently did not necessarily repeat it in their task solution. Consequently, there are no explicit data of instructional support methods that prove their effectiveness on justifications in task solution – neither on the collaborative nor on the individual task solution. Therefore, this is an important further research question.

Research questions

(1) How far do script and content scheme affect argumentation? Regarding argumentation as a twofold ability including transactive and reasoning processes, the effects of the support methods must be divided into two sub-questions:

(1.1) How far do script and content scheme affect transactivity in argumentation?
(1.2) How far do script and content scheme affect justifications of single arguments?

(2) How far do script and content scheme affect argumentation in task solution? There are two ways of measuring the influence of instructional support methods on argumentative task solution: task solutions worked out collaboratively and individually. Therefore, we need two separate questions:

(2.1) How far do script and content scheme affect argumentation in the task solution worked out collaboratively?
(2.2) How far do script and content scheme affect argumentation in the task solution worked out individually?

Method

Sample and design

One hundred and fifty-six undergraduates of the University of Munich took part in this experiment. Most of the undergraduates were in the second semester. 52 triads were randomly assigned to one of four conditions in a 2x2-factorial design. We varied the factors script (with/without) and content scheme (with/without). Therefore, there were four different conditions: condition with script (13 triads), condition with content scheme (13 triads), combination condition with script and content scheme (14 triads), and control condition (12 triads).

Learning task

Learners had to familiarize themselves with Attribution Theory in an individual learning unit. In a collaborative learning unit three participants had to solve a task together, which described the decrease in a student's performance. Learners received general information that included the cover story and the plot. Furthermore, they got specific information that focused on three perspectives relevant for solving the task – one divergent perspective for every learner. This included the perspective of the student, of the student's mother and the student's teacher. With the help of this specific information they were asked to find explanations and reasons for the student's decrease of performance by applying Attribution Theory. Therefore, two kinds of explanations are relevant: on the one hand, learners had to justify their task solution with theoretical classifications according to Attribution Theory and on the other hand with relevant information of the case. To evoke argumentation, some information in the three perspectives was oppositional.

Learning environment

The whole learning unit was subdivided into an individual and a collaborative learning unit. In the individual learning unit, learners had to read the text about Attribution Theory in order to solve the task together and in order to create a collaborative case solution in the form of a text document. In the collaborative learning unit, learners were connected via a desktop videoconferencing system with audio- and video-connection and a shared application to support the triads' task solution. The shared application functioned as external representation of the joint solution.

Treatments

Both treatments provided a pre-structure of relevant task aspects concerning collaborative task solving and content-specific strategies.

Script. The script structured the collaborative task solving unit into four phases alternating individual and collaborative phases. Each phase consisted of special activities, which the learners had to follow for their collaborative task solving (see figure 1). The first, individual phase consisted of text reading and excerption of the relevant case information. In this first phase, the learners had to consider the main causes mentioned in the specific perspective they worked on and had to write them down. In the second, collaborative phase, learners had to exchange their different information concerning the case. As the information of the perspectives differed in certain ways, it was necessary to discuss the varying causes and possible solutions argumentatively. All issues which were relevant for the solution of the case were to be transferred into the document template. After mentioning and noting all main issues, the learners had to reflect on the appropriateness of the jointly developed notes in the third phase. In the last, fourth phase learners had time to discuss special issues they reflected on in the third phase and had to work out a final version of the task solution.

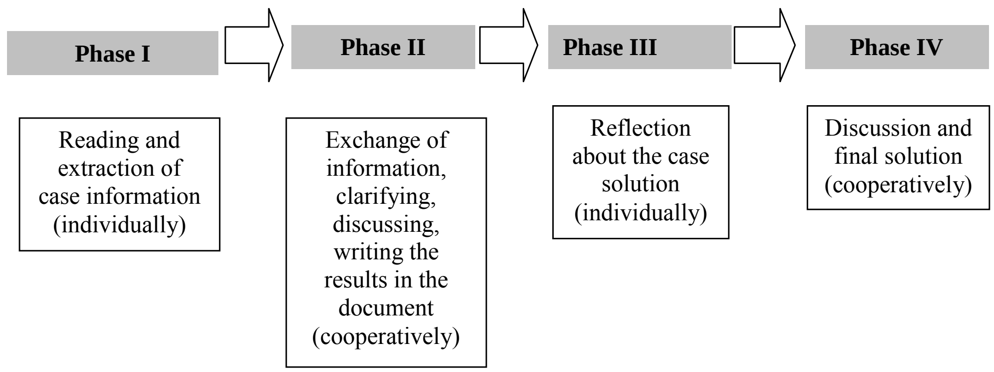

Figure 1: Script

Content scheme. In the condition with content scheme, learners received a content-specific structure of the relevant components concerning Attribution Theory (see table 1). This structure includes cause, information and attribution. Depending on divergent case information, different causes had to be mentioned. To confirm the causes, further information about consensus and consistency was necessary. According to Attribution Theory, consensus and consistency must be classified as high or low and explained with case information. The last category includes attribution according to Kelley (1973) and Heider (1958).

Table 1: Structure of the content scheme with an example

Cause	Information about		Attributions according to	
	Consensus	Consistency	Kelley	Heider
Laziness	Low because he is the only one in class who is lazy	High because he has been lazy for a year now	Person	Internal, variable

Data sources

Argumentation. To investigate argumentation, the discourse was analyzed according to transactive actions and reactions in argumentation and according to the justifications of arguments. In respect to this, a categorization scheme was developed that classified every single turn of the learners' discussion. Ten per cent of these discourses were rated independently by two evaluators.

Transactivity comprised four categories: statement, confirmation, counterargument, and reply. A statement was rated when a learner expressed his point of view on possible causes for the decrease in performance. A statement always included new information and was never related to previous propositions. Confirmation, counterargument and reply were transactive reactions. They could either be related to statements or to another transactive reaction. Did a learner agree with a point of view of his collaborating partner, he confirmed this statement. If there was no agreement, but an opposing statement, it was rated as counterargument. All other transactive reactions like evaluations, integrations or conclusions were in a first step coded separately and in a second step put together as reply. The inter-rater reliability was Kappa .83.

The justifications of arguments were rated according to two categories: with and without justification (Astleitner, 2003). Statements with justification were full arguments with premises and conclusions (e.g. "I think because consensus and consistency is high, it must be an attribution on the object."), statements without justification were assumptions, claims or hypotheses (e.g. “This is an attribution on the person.”). The inter-rater reliability for this categorization was Kappa .90.

Task solution. To measure whether the intervention influenced justifications in the task solution, two different case solutions were analyzed: a case solution worked out collaboratively and individually. These cases were rated according to reasoning processes which were manifested in justifications. Thus, all justifications in case solution were rated. These justifications comprised theory and evidence which are necessary for solving scientific tasks (Kuhn, et al., 1992), respectively theoretical classifications and case information. For ensuring inter-rater reliability of data, two evaluators analyzed 10 per cent of case solutions independently according to the rating scheme. For the collaborative case the Kappa was .86 and for the individual case the Kappa was .92, which were both sufficient. Due to technical problems, two collaborative case solutions get lost. Therefore, only 50 case solutions instead of 52 entered the analyses.

Statistical analyses. In the statistical analyses, we used as a unit of analyses the triad for our collaborative measurements like argumentation and collaborative task solution and the individuals for the individual task solution. We used multivariate ANOVAs with two between-subject factors to analyze the effects of both interventions as well as their interaction on the dependent variables argumentation, collaborative and individual task solution. The statistical tests underlie an alpha level of .05. The discourse examples of argumentation were investigated and analyzed according to transactive reactions and justifications. Although the total time for collaboration was kept constant, the four conditions differed in their collaborative time on task. Scripts reduced the time learners had to collaborate with each other by 10 minutes ($F(1,48)=195.7$; $p<.01$; $\eta^2=.80$). Therefore, we used time as covariate in our data analyses concerning argumentation.

Results

Research question 1: Effects of script and content scheme on argumentation

Taking a closer look at *transactive reactions*, the descriptive statistics shows most utterances concerning the categories statements, counter-arguments and replies in the condition with content scheme (see table 2). Regarding the effects of script and content scheme on transactive reactions, there was one effect of content scheme on statements: Learners with content scheme uttered 25 per cent more statements than learners without content scheme ($F(1,47)=5.83$; $p<.05$; $\eta^2=.11$). There were no further effects and there was no interaction either, even when subdividing the category reply in its subcategories evaluation, integration, and conclusion.

Table 2: Means and SD’s of transactive reactions in the learning discourse

	Statements		Confirmations		Counter-argument		Replies	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control	58.78	28.06	41.94	27.05	14.77	14.73	64.59	28.22
With script	67.53	26.62	25.89	11.43	14.84	9.87	55.87	17.66
With scheme	81.27	29.73	38.74	20.72	15.61	8.64	64.16	17.14
With script and scheme	82.46	27.00	40.06	10.36	20.55	10.46	67.41	14.81

The *justifications of arguments* should be influenced by content scheme (see table 3). Learners with content scheme used both categories – utterances with justification ($F(1,45)=4.03$; $p<.05$; $\eta^2=.08$) and without justification ($F(1,47)=4.27$; $p<.05$; $\eta^2=.08$) – more often than learners without content scheme. Both effects reached the level of significance.

Table 3: Mean and standard deviation of justifications in the learning discourse

	Justifications			
	without		with	
	M	*SD*	*M*	*SD*
Control	53.47	33.04	20.08	12.74
With script	65.45	31.03	16.93	9.89
With scheme	72.06	28.95	24.82	7.97
With script and scheme	81.28	27.46	21.73	9.71

Research question 2: Effects of script and content scheme on argumentation in task solution

The second question asks, whether script and content scheme had an influence on the justifications of the learners' task solutions, collaboratively and individually. Regarding collaborative task solutions analysed on a group level, learners in the condition with script and content scheme justified their task solution most often with relevant case information (see table 4). The highest score of the combination group with script and content scheme was confirmed by an ANOVA. There was a middle-sized effect of the script ($F(1,46)=4.90$; $p<.05$; $\eta^2=.10$) and a main effect of the content scheme ($F(1,46) = 51.14$; $p < .01$; $\eta^2 = .53$), but no interaction. Justifications with theoretical classifications were fostered by content scheme: Learners with content scheme justified their task solution almost twice as often with theoretical classifications than learners without content scheme. This was a main effect ($F(1,46)=51.52$; $p<.01$; $\eta^2=.53$).

Table 4: Mean and standard deviation of justifications in the collaborative task solution

	Justification with theoretical classifications		Justification with case information	
	M (max. 20)	*SD*	*M* (max. 15)	*SD*
Control group	9.82	4.69	4.82	1.54
With script	7.38	4.23	5.69	2.50
With scheme	16.77	3.32	9.15	3.13
With script and scheme	16.69	3.73	11.38	2.33

Examining individual task solutions, we found almost the same results (see table 5). Thus, learners with script and content scheme showed the highest score in justifying their task solution by giving adequate information. Both interventions had a beneficial effect on the justification with task information in the individual task solution. This showed a multivariate ANCOVA with prior knowledge (justification with case information and theoretical classifications) as covariate. Script ($F(1,150)=7.98$; $p<.01$; $\eta^2=.05$) and content scheme ($F(1,150)=17.75$; $p<.01$; $\eta^2=.11$) had both small effects. In respect of justifications with theoretical classifications, learners with content scheme justified their task solution twice as often with adequate theoretical classifications than learners without content scheme ($F(1,150)=38.78$; $p<.01$; $\eta^2=.21$).

Table 5: Mean and standard deviation of justifications in the individual task solution

	Justification with theoretical classifications		Justification with case information	
	M (max. 8)	*SD*	*M* (max. 6)	*SD*
Control group	2.67	2.04	1.86	1.51
With script	2.54	1.90	2.18	1.57
With scheme	4.60	2.79	2.55	1.80
With script and scheme	5.33	2.72	3.87	1.91

Summary and Discussion

Results of the study showed some effects of the intervention on argumentation as well as on task solution. Regarding argumentation, we analyzed transactivity as well as justifications in argumentation. Transactive reactions, especially stating opinions, were mainly fostered by content scheme. In combination with script, the amount of statements, counter-arguments and replies could be improved on a descriptive level of analyses. Justifying argumentation was fostered by content scheme. In respect to task solution, both script and content scheme had a positive influence: Script improved justifications with case information, content scheme justifications both with case information and with theoretical classifications.

By structuring the collaboration into four phases and providing joint sub-tasks for collaborative task solution, the *script* supported learners in justifying their task solution, the collaborative as well as the individual task solution. In previous studies, the script showed positive effects only on the learning discourse (Ertl, Reiserer, & Mandl, 2002; Härder, 2004; Weinberger, 2003). On the individual task solution, however, the script did not have any positive effects (Ertl, Reiserer, & Mandl, 2002; Reiserer, Ertl, & Mandl, 2002). The collaborative task strategy of focusing on the exchange and the discussion of relevant information proved sufficient for the learners considering relevant information in task solution. This manifested itself in the learners justifying their task solution with adequate case information. Both the collaborative and individual task solving strategy was supported by script. In contrast to previous studies, learners internalized the task strategy of the script, so that they could apply it to their own individual task solution (King, 2007). But the strategy had no effect on transactive reactions in the learning discourse as was hypothesized due to the sub-tasks of the script which were only illustrated in the discourse examples. To sum it up, the collaboration strategy provided by script manifested itself in collaborative and individual task solution by justifications with relevant case information. It did not manifest itself, though, in transactivity. This last result can be due to the fact that the script did not force learners to react transactively to each other according to a strictly limited structure of argumentative collaboration. Further on, the script probably reduced the need for transactive reactions, because individuals were better prepared for collaboration due to the individual reflection phase. But in combination with a content-specific strategy both intervention methods can improve transactivity in the learning discourse.

The *content scheme* made the most important aspects of the content salient. Due to the representational guidance of this table (Suthers, 2003; Suthers, & Hundhausen, 2003), learners got focused on the empty spaces they had to fill in with task relevant aspects. Thus, the content scheme affected argumentative discourse as well as task solutions. Concerning argumentation, the content scheme supported transactivity and justification in argumentation. As important aspects of the task were permanently represented, learners got focused on their own perspective so that they uttered more statements. Concerning the higher degree of counter-arguments and replies on a descriptive level, eventually the same mode of action of the content scheme could be assumed for this result, even though there was no significant effect. As learners knew which aspects they should focus on, they evaluated arguments more adequately. This in itself lead to more counter-arguments as discrepancies were discovered and to more replies resulting from evaluating or concluding. Moreover, for solving the task adequately it was necessary to justify every theoretical classification and case information that would be filled in the empty spaces of the content scheme. This implicit demand manifested itself in the argumentation discourse as more arguments with justifications were constructed. These results are in line with other studies using content scheme as support method (Fischer, Bruhn, Gräsel, & Mandl, 2000; Suthers, & Hundhausen, 2003). In these studies, learners with content scheme were able to relate hypothesis to evidence, that is in our study theoretical classifications to case information. In addition, content scheme fostered not only argumentative discourse, but also justifications in collaborative and individual task solutions. So far, the content scheme had mostly positive effects on the collaborative task solution (Baker, & Lund, 1997; Kanselaar, et al., 2003; Suthers, 2003), but not on the individual task solution. Possibly, the previous content schemes were too unspecific (De Jong, et al, 1998), so that learners could not acquire the content as well as an implicit task solving strategy. This was possible in the study at hand. Thus, learners were able to justify their task solution collaboratively and individually both with adequate theoretical classifications and with case information.

Conclusion

Concluding, both interventions had a positive influence on argumentation which was reflected in the learning discourse and in the collaborative as well as the individual task solution. The script offered a collaborative task strategy that fostered the argumentative exchange of information, while the content scheme made important components of the task solution salient which particularly supported activities of justification. Looking at the application scenario, we can see that indirect support methods directly implemented in the learning environment can affect scientific argumentation activities positively by providing both a collaborative and content-specific task solving strategy. Since argumentation is a very important ability in science, it would be interesting to find out, whether these effects could be replicated in other domains and settings.

In contrast to previous studies both support methods had an effect not only on argumentative collaboration and task solution, but also on the individual task solution. This means that learners were able to acquire not only the content, but also strategies for the application of their argumentative knowledge for task solutions. This effect can be due to the specificity of the instructional support (De Jong, et al., 1998). To sustain this assumption, further analyses concerning this aspect would be helpful.

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From Theory of Mind to a Theory of Distributed Shared Sense-Making

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Abstract. The current study proposes conceptualizing human intellectual activity in terms of mutually constitutive interactions among a distributed network of sense-making systems, rather than as individual cognition/learning situated in sociocultural context or as individual participation/apprenticeship in collective social practice. The model of distributed shared sense-making incorporates mutually constitutive interactions among sense-making systems, among mental models of sense-making systems, and between sense-making systems and their mental models. The model provides an integrated theoretical framework to support empirical examination of interactions among humans, and among humans and their cultural tools—in particular, their technological tools. The study uses the proposed theoretical framework to interpret teacher-student developing interactions in a technology-rich middle-school science classroom over the course of a year of scaffolded introduction to inquiry-based science instruction.

Theoretical Framework

Recent debate in the educational literature has focused on two foundational questions of human cognition/learning: Where is the mind (Cobb, 1994a, b), and how should learning be characterized (Anderson, Reder, & Simon, 1996, 1997; Greeno, 1997). The discussion has focused on teasing apart the subtle distinctions between dichotomous perspectives—social constructivism versus socioculturalism (Cobb, 1994a,b; Driver, Asoko, Leach, Mortimer, & Scott, 1994), cognitive versus situative learning (Anderson, Reder & Simon, 1996; Greeno, 1997), acquisition versus participation metaphors for learning (Sfard, 1998), and interaction versus intersubjectivity (Kieren, 2000; Lerman, 1996, 2000; Steffe & Thompson, 2000)—in order to engage in a meaningful discussion of human intellectual activity/ development.

A number of researchers have suggested that neither half of these various dichotomies provides an adequate picture of human intellectual activity/development (Cobb, 1994a,b; Driver et al., 1994; Greeno, 1997; Kieren, 2000). Greeno (1997) proposed that what is needed is a synthesis of the separate lines of cognitive and situative research into one coherent theory of social interaction and cognitive processes.

Human Systems of Distributed Shared Sense-making

The current study follows the direction proposed by Greeno (and Vygotsky (1978)) and attempts to contribute to efforts synthesizing a coherent theory of social interaction and cognitive processes. Toward that end, we conceptualize human intellectual activity/development in terms of shared sense-making rather than as individual cognition/learning situated in sociocultural context or as individual participation/apprenticeship in collective social practice. We develop a model of distributed shared sense-making through integration of the following key ideas: (a) elaboration of Vygotsky's (1978) zone of proximal development (ZPD); (b) elaboration of a construct termed the interaction space (or I-space), an extension of the *n*-dimensional space describing development of psychosocial entities originally proposed by Harré (1984); (c) elaboration of Tomasello's ideas of perspectival shift, joint attentional/referential fields, and shared intentional agent (Tomasello, 1999; Tomasello, Carpenter, Call, Behne & Moll, 2005); (d) elaboration of a broad definition of theory of mind (Astington & Olson, 1995; Hatano, 2002, 2005; Lagattuta & Wellman, 2001); and (e) cohesive tools (Halliday & Hasan, 1976).

We propose that Vygotsky's construct of the zone of proximal development can be fruitfully extended to designate a human system of shared sense-making, and human cognition can thus be fruitfully conceptualized as distributed across a network of mutually constitutive sense-making systems and mental representations of those systems. We propose conceptualizing an interaction space or I-space (as extended from Harré (1984)) to characterize sense-making interactions among sense-making systems and mental models. Interactions can be characterized in terms of the three major dimensions that describe the

I-space—realization, definition/ideas, and convergence/control. Movement within the I-space—that is, changing interactions—can be characterized in terms of *perspectival shifts*, shifts across dimensions (realization⇔definition/ideas⇔convergence/control) or shifts in perspective from one sense-making system to another along the same dimension. The interaction space can also be characterized in terms of the components that comprise the space—the network of sense-making systems, mental models of those systems, and the processes that function to develop coherence among the systems and mental models.

Coherence Processes: Inquiry and Reflection

We conceive sense-making systems to be mutually constitutive with mental models of those systems and to include processes for developing coherence among sense-making systems and mental models. In particular, we conceive of inquiry and reflection as two mutually constitutive coherence processes, through which humans systematically "open" to consider multiple possible interconnections among actions/ideas and then "close" to a single "best fit" option based on culturally developed criteria of consistency, repeatability, fruitfulness, and/or robustness.

Tomasello (1999) proposed that what may be unique about human cognition is not our ability to innovate, but rather our ability to ratchet; that is, our ability to distribute innovations among other humans in order to form a new basis for further innovation/ratcheting. Tomasello and colleagues (2005) further proposed that an important aspect of human cognition may be our ability to act as shared intentional agents—constructing dynamic interactive models of our own and others' minds to enable such ratcheting/shared sense-making. Conceiving of inquiry and reflection as coherence processes within a network of distributed shared sense-making suggests a potentially powerful role for such processes in developing complex networks of minds—multiplying human mental processing capacity by enabling integration of experiences and perspectives from multiple minds—a process that may be unique to human mental processing.

Methods

To demonstrate the utility of the proposed theoretical framework to describe important aspects of teacher-student shared intellectual work, we used the above framework and methods of conversation analysis (Psathas, 1995) to characterize developing teacher-student interactions in a technology-enriched middle school science classroom over the course of a year-long scaffolded introduction to inquiry-based science instruction (see Ladewski (2006) for a more complete description of the study methods).

An interpretive case study comprised of "telling" mini-cases (Knobel, 1996) was developed to capture both the subtle nuances of teacher-student interaction as they unfolded over the course of a lesson and also as they changed over extended time. Primary data sources used in developing the case study included videotaped and transcribed recordings of nine key lessons—four 45-minute lessons from each of two project-based units that spanned a year of instruction, as well as a culminating end-of-year student-designed investigation. Other data sources—including teacher semi-structured interviews, teacher-written case reports, and videotapes of teacher professional development worksessions—provided additional data to corroborate the story told by the mini cases.

We characterized sense-making interactions in terms of the following constructs of shared sense-making: (a) *joint attentional field*—on what object was joint attention focused and by whom; (b) *referential field*—what ideas/links were added to the referential field and by whom; (c) *perspectival shifts*—what shifts in perspective were initiated and by whom, and what corroborating or conflicting ideas/experiences were added to the referential field as a result of the shift; (d) *inquiry and reflection*—what processes were carried out to develop coherence among experiences and ideas within/among sense-making systems, and who initiated/participated in those processes; and (e) *cohesive tools*—what cohesive elements were added to link elements within the referential field and by whom.

Conclusions/Implications

Empirical findings indicate that perspectival shifts became increasingly frequent in number and increasingly diverse in terms of type during teacher-student interactions across the year of scaffolded introduction to inquiry-based science instruction. Initially the most common perspectival shifts were collective⇔individual realization, as the teacher modeled and her students then enacted prescribed experimental procedures in the classroom. Over time, teacher and students began to orchestrate additional perspectival shifts, including realization⇔definition (description), action⇔definition (explanation), and closed⇔open control (nascent inquiry/reflection); students also began to initiate perspectival shifts. Thus, experiences with inquiry-based instruction seemed to provide templates of sense-making that began to change the shape of sense-making itself. However, few cohesive tools linking or synthesizing ideas and/or experiences over extended time were contributed by either teacher or students.

The theory development adds to an emerging cross-disciplinary area of research exploring the integration of the psychological and the social. A model of distributed shared sense-making provides a potentially fruitful theoretical framework for characterizing human sense-making systems and developing interactions among such systems—and thus for examining the role of technological tools (and perhaps also the unique role of humans) in such sense-making systems.

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The role of problematizing moves in online knowledge building activities

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Abstract: This paper employed the method of problematizing moves (Koschmann et al., 2005) to study the online discussion of two groups of fifth grade students with one group more experienced in knowledge building (Bereiter, 2002; Scardamalia, 2002) than the other. Productive discussions could be resulted even without the assistance of teachers, through the problematizing moves made by the students themselves. Students having more experience in knowledge building seemed to be better at initiating the problematizing moves. However, the initiation also requires the uptakes of other learners so that the inquiry could be sustained. There was evidence that the novice group learned to ask more questions in the discussions, but their questions could still not be qualified as problematizing moves, suggesting further guidance might be needed. Relevant issues such as culture, gender, and the concept of "group" in a CSCL context were also discussed in this paper.

Introduction

In the paper that put forward a thematic agenda for the next decade of computer-supported collaborative learning (CSCL), Suthers (2005) argued that what makes this field unique is the computer support for "intersubjective meaning making", which implies learning is not only accomplished through interactions but also composed of those interactions (Koschmann, Zemel, Conlee-Stevens, Young, Robbs, & Barnhart, 2005, cited in Suthers, 2005). As CSCL environments can turn communication into substance (Dillenbourg, 2005: p.260), the joint meaning making process among participants is made visible and could be studied. Although there are studies that examined social interactions through "coding and counting", the study of joint meaning making is still not prominent in the field of CSCL (Stahl, Koschmann, & Suthers, 2006). Aligned with this new research focus, Stahl (2006) proposed small groups as the primary unit that mediates between individual learning and community learning. Within small groups, through the discourse displayed by the members, their meaning making process could be observed. Koschmann et al. (2005) proposed the method of "problematizing moves" to investigate how groups of learners identify a situation as problematic and requiring further inquiry. This type of research is at the beginning stage (Suthers, 2005). This paper attempts to use the method of problematizing moves to look at the online discussion of two groups of fifth grade students with one group having much more experience in CSCL activities combined with the knowledge building approach (Bereiter, 2002; Scardamalia, 2002) than the other. Two episodes are selected to see what factors might contribute to the successfulness or unsuccessfulness of problematizing moves. The relationship of knowledge building and problematizing will also be explored.

Knowledge building as a learning goal for CSCL

According to Bereiter (2002) and Scardamalia (2002), knowledge building is the process through which knowledge advances in human societies, and that learning can also take place as a process of knowledge building. The theory of knowledge building can become a theoretical rationale and pedagogical basis for CSCL. In a shared network space provided in a CSCL setting, students could make their ideas explicit and share with others with a goal to advance the knowledge of the collective to become a knowledge building community. The knowledge building approach emphasizes the importance of collective cognitive responsibility and communal efforts to improve ideas and to advance the knowledge of the collective (Scardamalia, 2002). A total of 12 knowledge building principles were elaborated by Scardamalia (2002) to distinguish a knowledge building classroom from even the best of traditional and modern classrooms. These 12 principles include "idea diversity", "democratizing knowledge", "community knowledge, collective responsibility", "improvable ideas", "epistemic agency", "knowledge building discourse", "real ideas, authentic problems", "rise above", "symmetric knowledge advancement", "pervasive knowledge building", "constructive uses of authority sources", and "embedded and transformative assessment" (Scardamalia, 2002). Based on these 12 knowledge building principles, Law & Wong (2003) studied a number of CSCL groups and found consistent patterns of development across groups in that characteristics described by some of the principles were exhibited before the others, while the characteristics of some of the principles were much more difficult to be observed. They reported on their findings in the form of a developmental trajectory in knowledge building. This developmental trajectory broadly paralleled Gunawardena, Lowe, & Anderson (1997)'s five phases of knowledge construction (see Law, 2005): (1) sharing/comparing of information, (2) discovery and exploration of dissonance or disagreement, (3) negotiation of meaning or knowledge co-construction, (4) testing tentative constructions, and (5) application of newly constructed knowledge. In other words, for students to become more advanced in knowledge building, they need to move from sharing or comparing information to the discovery of disagreement, negotiation of meaning and beyond. Other researchers employed the depth of explanation, that is, whether the discourse is fact-oriented or explanation-oriented, to differentiate students' levels of knowledge building (e.g., Lipponen, 2000; Hakkarainen, Lipponen & Jarvela, 2002). However, the method of problematizing moves has not yet been applied in the context of knowledge building.

Problematizing and knowledge building

To better understand how learning takes place in interactional contexts, Koschmann et al. (2005) proposed the concept of "problematizing moves", which is "a form of social action that has the effect of calling something previously held to be so into doubt" (p. 265). The concept of problematizing moves draws on Dewey (1938/1991)'s idea of inquiry that "a problem is not a task to be performed which a person puts upon himself or that is placed upon him by others" (p. 111). To problematize learners have to discover something which is potentially problematic. In Koschmann et al. (2005)'s terminology, a problematizing move serves the functions of directing attention to some potentially problematic matter, as well as projecting some form of collective action with regard to that matter. Koschmann et al. (2005) illustrated with two examples, one face-to-face and the other online, that the strategy of problematizing moves could be applied to analyze how learning takes place in interactional settings. In both examples, the analysis began with a prelude to problematizing, followed by the problematizing moves initiated by the learners, and the uptakes of other members. Koschmann et al. (2005) concluded that even there might be communication constraints in online settings, the methods employed by learners to problematize a problem are similar to those in face-to-face contexts.

As one characteristic of knowledge building is the focus on problems that learners really care about (Scardamalia, 2002), it could be seen that the concepts of knowledge building and problematizing are closely related. Knowledge building emphasizes on learners' "epistemic agency"; problematizing also requires the moves to be initiated by learners themselves. Calling something previously held to be so into doubt requires putting forward ideas that are different from those shared by the majority and moving beyond current levels of community knowledge; these could be represented by the knowledge building principles of "idea diversity", "democratizing knowledge" and "rise above". The collective action towards the problematic matters and the uptakes of other members are closely related to the principles of "community knowledge, collective responsibility", "improvable ideas", and "knowledge building discourse". In the literature of knowledge building, teachers are found to be a critical factor to engage students in deeper levels of knowledge building. In Koschmann et al. (2005)'s paper, although the authors did not make it clear whether the presence of a facilitating tutor is necessary in problematizing moves, the tutor played a significant role in helping the learners to direct their attention towards the potentially problematic matter in both the face-to-face and online examples. This paper does not attempt to address the issues related to teachers or tutors, but focus on the interaction between two groups of same-grade students with one group having much more experience in knowledge building than the other.

Peer scaffolding in a CSCL environment

Generally speaking, in a CSCL environment, scaffolding could be provided by human agents such as teachers and peers or by the artifacts embedded in software designs (e.g., Brush & Saye, 2002; Lajoie, 2005). In a recent overview, Reiser (2004) summarized two major and complementary mechanisms that educational software tools could provide scaffolding. Firstly, software tools could help structure the task to guide students through key components as well as support their planning and performance. Secondly, the tools could problematize important contents so that students would devote resources to issues they might not otherwise attend to. It should be noted that both Reiser (2004) and Koschmann et al. (2005) used the term "problematizing" and their meanings are in fact quite similar; the focus of the former is on how software tools could provide this function while the latter on how people actually do it in social settings, including both online and face-to-face contexts. However, Reiser (2004) also mentioned that "the social context of collaborative problem solving is often integral to the problematizing nature of the tool" (p. 289), suggesting that for the problematizing function to be effective, human involvements such as peer collaboration have to be included. The concept of peer scaffolding founded on the theories of Vygotsky and Piaget. With his notion of zone of proximal development, Vygotsky (1978) mentioned the benefits of interacting with a more capable peer. Piaget did not consider inequality in competence to be necessary (see e.g. Tudge & Rogoff, 1989) and focused more on peer interactions through which children with differing perspectives could create socio-cognitive conflicts that result in construction of new conceptual structures and understanding (see also Doise & Mugny, 1984). From the perspective of knowledge building, the focus is not on how individual learners could be benefited from the interactions or how the cognitive process of an individual operates, but on extending the knowledge and understanding of the whole community beyond the initial state of knowledge of the collective community through intentional social interactions. The concept of problematizing moves is considered in this paper as a key to understand how the community knowledge could be advanced.

Issues of methodology in CSCL

In the field of CSCL, there are basically three major methodological approaches: experimental, descriptive, and iterative design, as summarized in Suthers (2005)'s paper. The experimental approach usually involves the comparison of an intervention to a control condition and the data are analyzed through the method of "coding and counting". The descriptive or ethnomethodological approach is usually microanalytic and involves the examination of some episodes in greater detail; the method proposed by Koschmann et al. (2005) is an example of this approach. The iterative design approach involves the continuous improvement of software and pedagogical designs which is driven by the dialectic between theory and implementation. Suthers (2005) did not argue the importance of one approach over the others, but rather called for a methodological fusion that combines the strengths of different approaches. In the area of research design, "triangulation" is often used to refer to the condition that multiple or mixed methods are being employed. Triangulation is a metaphor borrowed from land surveying, which states that if we know the exact positions of two points, we can locate an unknown third point by projecting an angle from each of the two known points. When this metaphor is applied to the setting of research design, it is not clear what exactly each of the points mean and what different methods or combinations of methods should be employed in a study (for more on triangulation, see e.g., Erzberger & Kelle, 2003; Gorard & Taylor, 2004). In Chinese characters, there are three words constructed with the same component *mu*. As shown in figure 1, the single-component word *mu* means a tree; while the combinations of this component will become the words *lin* and *sen*, both meaning a forest. Interestingly, the word *sen* has the shape of a triangle, with its upper part meaning a tree and lower part a forest. This triangular-shaped word might provide a new metaphor for triangulation, which implies "seeing the tree as well as the forest". In other words, in choosing those multiple analytic methods, there should be some focusing on the detail, that is seeing the tree, while others focusing on the overall picture, that is seeing the forest. To triangulate is to supplement a detailed analysis with a whole-picture one, or a whole-picture analysis with a detailed one. The method of problematizing moves attempts to study human interacting episodes in great detail, in order to look at the whole picture, especially on the changes in discourse patterns over different stages of collaboration between the two groups of students, the detailed analysis in this paper is "triangulated" with a "coding and counting" method based on the five phases in knowledge construction proposed by Gunawardena et al. (1997). The coding scheme of Gunawardena et al. (1997) was chosen because it is one of the methods that can reflect the levels of knowledge building (Law, 2005); and compared to other coding methods, such as those distinguishing between fact-oriented and explanation-oriented discourse (e.g., Lipponen, 2000), Gunawardena et al. (1997)'s coding scheme included the category of "discovery of dissonance or disagreement", which is closely related to the concept of problematizing, as they both require the learners to discover something to be potentially problematic.

木	林	森
mu	*lin*	*sen*
tree	forest	forest

Figure 1. The three Chinese words with the meanings of tree and forest.

Research Design and Methods

This current study was based on the collaboration between two primary school teachers, one in Hong Kong and the other in Toronto, Canada. The Canadian teacher is teaching at a laboratory school of the University of Toronto and has more than four years of experience in facilitating students to engage in online knowledge building activities while the Hong Kong teacher and his students were new to this novel approach. The international collaboration was set up when the two teachers met at an international conference. The Hong Kong teacher was interested in trying out this new pedagogical approach and the Canadian teacher wanted to scaffold the Hong Kong collaborators, both the teacher and his students, through online collaborative knowledge building of the two classrooms. As a result, the two teachers agreed that their students, 22 from Hong Kong and 22 from Toronto, all at grade five, would collaborate through the online platform Knowledge Forum® during the school year 2004-2005.

The online platform

Knowledge Forum® (KF), the online discussion platform used in this study, was developed by Marlene Scardamalia and Carl Bereiter's team at the University of Toronto to support asynchronous collaborative knowledge building activities (Scardamalia & Bereiter, 1992). KF creates a shared network space for students to write new notes, read other's notes and respond by writing build-on notes. Notes related to the same topic could be arranged in the same view. KF has a number of specific features to support knowledge building activities. First of all, its graphical display helps users to visualize their interactions with one another as each build-on note is linked to the note it responds to. KF also provides the function of "scaffolds" in the form of word cues such as "New information", "New idea", "I need to understand", and "My theory" so that students could better organize their note contents.

Participants' backgrounds

All the 22 Canadian students were from the same grade-five class in the laboratory school described above. These students had used KF as a learning environment fully integrated into their school learning experience since grade one. In fact, teachers in this school adopted not only the technology platform, but also the knowledge building approach in their pedagogical practices. While the Canadian students were experienced in knowledge building and the use of the technology platform KF, the 22 Hong Kong students were totally new to this online environment or the knowledge building approach. Although they were familiar with face-to-face discussions in class, they have never engaged in online knowledge building activities approach which emphasizes the continual improvement of ideas through intentional interactions with one another.

The collaboration process

Stage one: The current study began in the autumn term of 2004. As the Hong Kong (HK) students had no experience in online knowledge building activities, the two teachers agreed to start their collaboration only after the HK students had a chance to familiarize with working in KF. In Nov 2004, the 22 HK students formed five groups among themselves to work collaboratively on the online platform KF for two months to work on topics of bacteria, computer, dress-up, electric boat, and electricity. This two month period could be considered as stage one of this study in which HK students discussed among themselves on KF. At the same time, the Canadian (CA) students used KF to work on topics related to ancient civilizations which was one of their curriculum themes for the school year. No interaction of the two classes occurred during this stage.

Stage two: Beginning at the end of Jan 2005, HK and CA students started their online collaboration. During the first week, an "Introduction" view was set up for the two classes of students to introduce themselves to each other and to articulate which topics they were interested in. Since the HK students and their teacher were also interested in ancient civilizations, the CA students extended their exploration by one and a half months to collaborate with their peers in HK on eight topics related to ancient civilizations that were found to be of interest to both classes of students. The topics included building, clothing, Egypt, food, language, life style, religion, and weapon. During this period of international collaboration, HK students formed eight groups each responsible for one of the topics, although they were encouraged to join in the discussions of other topics. While on the CA side, students were allowed to freely join in the discussions of any topic they were interested. This period of time could be regarded as the stage two of this study.

Stage three: The joint-collaboration ended when the CA school closed for their term-break. When school resumed in the spring term, the CA class moved on to other topics and no longer appeared on the online collaboration space with the HK students. On the other hand, the latter class of students did not have a term-break at the same time and they continued to work on the eight ancient civilization topics till June. Thus although it was not planned intentionally, the end of joint-collaboration signified the start of stage three, which could be regarded as a "fading" stage (Collins, Brown, & Newman, 1989), as the more experienced group had withdrawn from the collaboration, leaving the novice group to continue the discussions by themselves.

Results and Discussion

To apply the method of problematizing moves proposed by Koschmann et al. (2005), two episodes each within a discussion thread were selected and analyzed. They were both created within stage two, in which the CA and HK students participated jointly in the discussion. The analysis was then "triangulated" with the findings based on Gunawardena et al. (1997)'s coding scheme. The results of two focus group interviews with the HK students after the collaboration were also presented and the corresponding issues were discussed.

Episode 1: Did most civilizations hunt?

The first episode was related to the topic of "food". Before the problematizing move, students were discussing when ancient people changed from hunting to trading for food. Thus an assumption beneath the discussion is that ancient civilizations usually hunted. A CA student posed the first problematizing move, questioning whether all ancient civilizations hunted for food. The following excerpts were extracted from the online discourse triggered by this problematizing move. The text inside brackets at the beginning of each entry denotes the scaffold selected by the student in that note.

CA student #1: [My theory]: Is that most civilizations hunted for food? It would be interesting if a civilization did not hunt.

HK student #1: [I need to understand]: Unless you count the tribes in Africa or India, I'm not really sure that people nowadays hunt for food. But people long time ago either hunted or farmed or even fished. But I don't know whether the people hunted more or farmed or fished more.

CA student #2: [Further explanation]: Most civilizations found that hunting was much harder to use to get food and most civilizations were agricultural societies (farmers) and hunted only a tiny bit.

HK student #2: I think Chinese hunted for food .Then they fished for food. Lastly they planted.

HK student #1: [New information]: The Chinese mainly farmed for food. They think that wheat is the most important food, that's why they had so many farms in a village. The season for them to plant is spring and they harvest the food in autumn, they do not work in winter. And when sometimes they can't grow any wheat, they hunt instead.

The first problematizing move received the uptakes of other students to further inquire on other means of getting food in ancient times. As the HK students are all Chinese, they quickly associated the discussion with their knowledge that ancient China was a farming society. When the students came to a shared understanding that ancient civilizations could also farm for food, the CA student posed another problematizing move, questioning how ancient people who farmed could have meat to eat. The second problematizing move again drew the attention of other students and they came to a new shared understanding that agricultural civilizations could raise animals to get meat, as indicated by the following excerpts that followed the above ones.

CA student #1: [I need to understand]: How did they get their needed meat?

CA student #2: [New idea]: The civilizations would probably only hunt when they needed the meat and be farmers for more of the time. Maybe they even just raised their own animals like chickens and cattle.

HK student #1: Yes, that's a good suggestion, I think it's right. I once read a book and the people usually slaughtered their own animals, they rarely hunted. That's why some people have to take care of the animals and the other are doing the farming.

With the two problematizing moves, the understanding of students became more and more complete, from recognizing that most ancient civilizations hunted, to some of them farmed, to those farming civilizations could also raise animals to get meet. From the perspective of knowledge building, it could be said that the collective knowledge has been advanced. Both problematizing moves were generated by the same CA student, while HK and other CA students participated in the discourse through their uptakes of the problematic matters. It should also be noted that the teachers did not involve in the discussions, the problematizing moves were initiated and up-taken by the students themselves.

Episode 2: Why some civilizations were more peaceful than others?

The first episode demonstrated how problematizing moves could lead to the sustained inquiry over the problematic matters so that the collective knowledge could be advanced; in the second episode, however, the initiation of a problematizing move did not result in sustained uptakes of other students. The episode is related to the topic of "weapon". A group of three HK boys was responsible for this topic. Before the problematizing move, they were gathering the information on weapons used in the past, such as the darts used by Japanese ninjas, and the swords used by ancient Romans. Then a CA student posed a problematizing move, questioning why some civilizations were more peaceful than the others.

CA student #3: [I need to understand]: I wonder why some civilizations were more peaceful than others? For instance the Mayans barely fought at all compared to the Romans who fought a lot.

CA student #4: May be the civilizations fought a lot depended on where they lived.

CA student #3: [Further explanation]: I think this might be true because the Mayans lived in a pretty remote part of the world (ancient Mexico).

HK student #3: [Further explanation]: It's the problem of the ruler or leader of the place. If the ruler likes to fight, then the place and all its people aren't peaceful at all.

The discussion thread ended with the note posted by HK student #3, who is not one of the three boys. Although there was a small degree of uptakes in this episode and ideas like whether the civilization lived in a remote place or whether the ruler loved to fight came out, the problematizing move did not trigger the sustained inquiry over the matter of why some civilizations were more peaceful than the others, which might turn out to be a productive discussion. The three HK boys did not participated in the discussion at all; they were still more interested in finding information about weapons and how ancient people fought and killed. One of the knowledge building principles, "symmetric knowledge advancement" (Scardamalia, 2002), articulates the importance of balancing the inquiries on different knowledge aspects. The three boys seemed to be too focused on their knowledge advancement in "weapons", while the discussion about peaceful matters was beyond their agenda.

Triangulation with Gunawardena et al. (1997)'s coding scheme

With the concept of problematizing moves, students' discussions could be studied in great detail. The two episodes seemed to suggest that CA students, who were more experienced in knowledge building activities, were better at initiating problematizing moves than their HK counterparts. However, to draw a more concrete conclusion, the results have to be "triangulated" with an analytic method that could look at the whole picture. In another study, Lai & Law (in press) coded the same set of data with Gunawardena et al. (1997)'s model of five phases in knowledge construction. Each discussion note was classified into one of the five phases based on the coding scheme proposed by Gunawardena et al. (1997). Phase 1 is called "sharing/comparing of information", including the statement of observation, opinion, or agreement. Phase 2 is called "discovery and exploration of dissonance or disagreement among ideas, concepts, or statements", including the identification of areas of disagreement, or clarification of the source and extent of disagreement; this phase could be regarded as closely related to problematizing as they both require the learners to discover some matters that are potentially problematic. Phase 3 is called "negotiation of meaning/co-construction of knowledge", including the negotiation or clarification of the meaning of terms, identification of areas of agreement or overlap among conflicting concepts, or proposal and negotiation of new statements embodying compromise and co-construction; this phase is closely related to the uptakes of other learners, as after the problematizing move, learners will devote their efforts in further inquiring on the problematic matters. Phase 4 is called "testing tentative constructions", including testing the proposed synthesis against received fact, or testing against contradictory testimony in the literature. Finally, phase 5 is called "application of newly-constructed knowledge", including the application of new knowledge. The first phase of sharing or comparing information could be considered as the lowest level in terms of a knowledge building discourse, while the second to fifth phases denote more advanced levels (Law, 2005). As the current study did not require students to come up with some knowledge constructions for testing or applying, Lai & Law (in press) did not find any note belonging to either phase 4 or phase 5. Table 1 summarized the coding results over the three stages of collaboration between the two groups of students; only the findings within the first three phases were presented.

Table 1: Classification of the students' note contents in each of the three stages using Gunawardena et al. 's (1997) coding scheme on phases of knowledge construction.

	Stage 1	Stage 2		Stage 3
	HK	HK	CA	HK
Phase 1: Sharing/comparing information	91%	67%	60%	81%
Phase 2: Discovery of dissonance	6%	13%	18%	5%
Phase 3: Negotiation of meaning	3%	21%	22%	14%

It could be seen that over the three stages, the majority of notes belonged to the first phase of "sharing information", especially during stage one when HK students discussed among themselves. With the joining in of CA students in stage two, more notes related to the "discovery of dissonance" were added by CA students, which in turns triggered the discourse of HK students towards "negotiation of meaning". When CA students no longer appeared in the discussion, HK students continued to discuss on the topics of ancient civilization, but their discourse was not characterized by the "discovery of dissonance". A possible reason could be that the discovery of dissonance, or the initiation of problematizing moves is more likely to appear in the earlier stage of inquiry. However, it is also likely that the CA students, at least some of them, with more experience in participating in knowledge building activities, were better at discovering dissonances, or problematizing the discourse than HK students.

Are students equally good at problematizing?

Although the results suggested that CA students were better at initiating the problematizing moves or discovering dissonances than HK students, it does not mean that all CA students were equally good at problematizing. Of the 22 CA students, only ten of them created notes which belonged to the second phase of Gunawardena et al. (1997)'s coding scheme, while the others only brought in discussion notes that were related to information sharing. Among the ten CA students, one created three second-phase notes, the other two each produced two second-phase notes, while the remaining seven each created only one second-phase note. The results suggested that those problematizing moves were initiated by a few students, though it is likely that owing to the limit of time for the stage of joint-discussion, other CA students did not have the opportunities to initiate problematizing moves. The CA student who question "why some civilizations were more peaceful than the others" also created a similar note in the topic of language, asking "why some languages are still around and others are not". It could be seen that the wording pattern used by this student was, "why some…and others…" The tactic used by the student who initiated the problematizing move in "food" was to question whether hunting as the major means of getting food could be applied to all ancient civilizations. It was also found that the CA students usually initiated a problematizing move with the scaffold of "I need to understand" or "My theory".

Did HK students notice any differences?

After HK students had finished the online discussions, two focus group interviews were conducted with six HK girls and seven HK boys respectively. They were asked with the question whether they noticed any differences between the notes written by them and by CA students. Both boys and girls mentioned the English of CA students was more fluent, but the girls also noticed that CA students asked more questions in their notes. To triangulate the interview results with the whole picture, the types of scaffolds used by students throughout the three stages were counted. As shown in table 2, the patterns of scaffold usage by HK students were quite consistent in stages one and two: about half of them were "New information", about 30% were "New idea", and about 10% were "I need to understand". The corresponding pattern for CA students was somewhat different: although half of the scaffolds used were also "New information", they tended to use more "I need to understand" (27%) and less "New idea" (13%). The results might reflect why the problematizing moves were mainly produced in stage two by CA students as the question-asking scaffold, "I need to understand", is more related to problematizing than other types of scaffold. It is noteworthy that in stage three, when the CA students withdrew, the HK students increased their usage of the scaffold "I need to understand" to 22%, suggesting that they might model their CA counterparts to ask more questions in their notes in the final stage. However, a closer look at the note contents will discover the questions asked by some HK students tended to be more information-oriented, suggesting that they might not fully grasp the meaning of "understand" in the scaffold, "I need to understand". For example, some HK students used this scaffold to ask questions such as "do you agree?" or in conjunction with the statement of "please tell me more what you mean". They might simply use it as "I need to know" instead of focusing on deepening their understanding. It should also be noted that HK students increased their usage of "New information" to 61% in stage three; this might be due to the fact that at the end of stage three, each group had to conduct a presentation on the topic of ancient civilization one was responsible for, so the HK students might try to look for information that were presentable; the results were in fact consistent with the analysis using Gunawardena et al. (1997)'s coding scheme as shown in table 1.

Table 2: Kinds of scaffold used in Hong Kong and Canadian students' notes during the three stages

	Stage 1	Stage 2		Stage 3
Scaffolds used	HK	HK	CA	HK
New information	49%	48%	49%	61%
New idea	27%	32%	13%	15%
I need to understand	13%	12%	27%	22%
Others	11%	8%	11%	2%

Issues related to grouping

During the international collaboration, CA students were free to join in the discussion of any topics they were interested, while groups were formed among HK students with each group responsible for one topic related to ancient civilization, though they were encouraged to join in the discussions of other topics as well. The participation statistics suggested that CA and HK students did not vary much on the numbers of topics they worked onto. In stage two, averagely speaking, each CA student participated in the discussion of 2.36 topics, while HK students worked onto 2.05 topics. In the focus group interviews, HK students were asked whether they preferred to participate in the discussion as group members or as individuals. The boys mentioned it was important to belong to a group so as to indicate one's devotedness to the topic, and it was not possible to have a deeper level of discussion if one belonged to many different groups. While for the girls, some preferred to work in groups while others said it was not important whether one belonged to a group, the concept of group identity could be flexible in the current context, as indicated by the following interview excerpt:

> When you are building on the notes in other topics, you will feel that you belong to a large group. If you simply look for the information of one topic, you will feel that you are a member of that group. So the membership changes in different times. (Interview transcript of a Hong Kong girl)

Recently, Stahl (2006) put forward the notion of "group cognition" to understand the importance of discourse in small groups in a CSCL context. Stahl (2006) spent several chapters to clarify concepts such as mediation by small groups, and whether collaborative groups could think. The concept of "group", however, seemed to be treated as unproblematic and not much words were spent on it in the book; it was used to contrast with individual learning (p. 5) and its size could vary from three to five (p. 19). In a face-to-face project-work setting, the concept of "group" or "group boundary" is more concrete. In a CSCL context, group boundaries are more blurred. Students can still form groups to carry out the discussion or inquiry, but their discourse is visible to other students who can join in the discussion at any time. The results of this study suggested that problematizing moves might not be easily initiated by all learners, so the flexibility of crossing group boundaries is important, or otherwise some groups may end up with only information-sharing discourse without any problematizing movements. The flexibility requires both the willingness to join in others' discussion and the welcome-ness of others to join in one's discussion. It is related to the knowledge building principle of "symmetric knowledge advancement" and further studies are needed on this issue.

Issues related to culture and gender

The two groups of students were from two different cultures, one Eastern and the other Western. There have been findings that people from Eastern cultures, which are more collectivist, tend to conform and agree more while people from Western cultures, which are more individualistic, tend to deviate and disagree more (see e.g., Nisbett, 2003). However, it should be noted that to disagree is not equivalent to problematizing or discovering disagreements or dissonances. In this study, the factor of culture is confounded with the experience in knowledge building. In future studies, they should be separated to see whether culture alone could make any significant difference on the discourse patterns.

The focus group interviews of HK students suggested that girls might be more flexible in crossing the group boundaries than boys. The participation statistics also indicated in stage two, HK girls tended to work onto more topics (2.64) than boys (1.45) and the difference was significant ($F(1,20)=6.86$, $p<.05$); though there was no significant gender difference on the number of notes created or number of notes read. Gender is thus a factor that worth further inquiry. If boys are really less likely to cross the group or topic boundary, intervention might be needed to help them appreciate the importance of the knowledge building principle of "symmetric knowledge advancement".

Conclusion

This paper demonstrates that problematizing moves could lead to productive discussions among fifth-grade students in a CSCL context. It was also found that students having more experience in knowledge building are better at initiating the problematizing moves. However, the initiation also requires the uptakes of other learners so that the inquiry could be sustained; it involves the issues of how to cross the group or topic boundaries, and more fundamentally how "group" should be conceptualized in the setting of CSCL. Although there was evidence that after the collaboration, the novice group tended to ask more questions, which might be the result of modeling from the more experienced group, the questions they asked could still not be counted as problematizing moves. It suggests that some more guidance might be needed; for example, the teacher could clarify with them the difference between "I need to know" and "I need to understand". This paper presents an international collaboration between two groups of fifth-grade students through an online discussion forum. As the whole world is increasingly connected, this type of international collaborative offers a promising way for future pedagogical designs in which productive discussions could be resulted even without the assistance of teachers, through the problematizing moves made by the students themselves.

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Let's Read Together: An Evaluation of a computer Assisted Reciprocal Early English Reading System

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Abstract. The purposes of this study were to evaluate the effect of a computer assisted reciprocal early English reading (CAREER) system. The results showed that these components were unable to guarantee the students to collaborate well when they lacked for the abilities to accomplish the assigned tasks. Nevertheless, with the support of the proposed mobile reading system the students were benefited by collaborating with each other.

Introduction

Students' reading abilities play an important role in their academic achievement. Research evidence shows that training in early linguistic skills improved children's reading performance, especially for those learners who are at-risk for reading difficulties (Lovett, Warren-Chaplin, Ransby, & Borden, 1990). In the field of EFL teaching, collaborative learning (CL) has been widely used in reading programs to implement the required intensity for mastery of early reading skills and provide students with learning support because of their sophisticated features such as small group, pair-work, and peer-assisted learning. In CL model learners are put at the center of learning process, and guidance and concrete teaching are provided whenever necessary. In a review of the literature on collaborative learning also affirmed its effect upon students' reading skills, such as promoting students' motivation (Ushioda, 1996), increasing reading outcomes (Slavin, 1988), pursuing group goal (Nichols & Miller, 1994), and decreasing EFL students' feeling of school alienation (Ghaith, 2003).

Even though collaborative learning has been known as an effective teaching method in EFL reading, few studies had focused on early EFL reading. The pedagogical challenges (such as students' diversity in reading abilities, the social-economic gap between rural and country, class size, limited teaching time, and available resources) becomes a problem when EFL teachers try to adopt collaborative learning in reading instruction in traditional EFL classes (Lan, Chang, & Sung, 2004).

Mobile technology is currently a feasible approach to overcoming many of the obstacles in current methods of EFL reading instruction. Standing on the shoulder of giant CALL (computer assisted language learning, e.g., Sung, Huang, & Chang, under review), MALL (mobile assisted language learning) has the capabilities of providing EFL learners with the same opportunities for independent and targeted reading practice and immediate corrective feedback as CALL. Considering the limited number of MALL studies focusing on early EFL reading skill training and fewer studies using elementary EFL learners as participants, the purpose of this research was to investigate how mobile technology benefits to elementary EFL learners' collaboration. Rather than measuring specific learning gains, this research focused on comparing students' collaborative behaviors found in two different EFL learning environments (without and with mobile device supports), and investigated that whether mobile learning could benefit students' collaboration. The following sections will give a brief description of methodology, results, and finally a discussion and conclusion.

Method

In order to understand elementary EFL learners' collaboration, we collected the video data from the two classes and then watched the vide data repeatedly. The video watch was focused on the how the groups behaved during the reading activities described in Procedure Section.

Subjects

The participants of this experiment were 52 forth graders in 2 classes from an elementary school of Taipei, Taiwan. Each class was first randomly assigned into an experimental group and a control group. Then the students were grouped into heterogeneous reading groups based on their level of English achievement in the third grade.

CAREER System

This study proposed a reading system called Computer Assisted Reciprocal Early English Reading (CAREER). CAREER consists of three modules: a sight word module, a phonetic word module, and a peer assessment module. The design strategy of the sight word module and the phonetic word module is based on a *scaffolding* foundation. When students are practicing and taking the test, CAREER provides them with the necessary scaffoldings. Students can hear and repeat after CAREER to say the sound of a sight word or a single phoneme. In contrast to the learning activities of word learning, the strategy used in the peer assessment module is *collaborative learning*. In the peer assessment module, CAREER first assigns each student a paragraph randomly drawn from the text. Next, CAREER asks the whole group to organize the complete story by sharing and discussing. Then, CAREER shows some comprehension questions on the screen and asks students to answer the questions by group discussion.

Procedure

Five teaching packages were taught in this study. A teaching package consisted of two two-lesson activities and was over a period of 2 weeks, two lessons per week, with a total of 160 minutes for each teaching package. In the first two-lesson activities, each student was assigned a randomly chosen subset of the teaching materials which focused on the training of sight words or phonetic words. Next, students were asked to read out the assigned subset of words individually. Then, they were asked to teach the other groupmates the subset of words which were assigned to them and also learn the other subsets of words from others. Finally, one student from each group was picked, by drawing of lots, to represent their group and attend the speed reading contest. If the attendant won then her/his team won.

In the second two-lesson activity, six steps were carried out step by step. Firstly, students reviewed the materials. Secondly, a randomly chosen paragraph of a written text was assigned to each student, and they were asked to read out the paragraph individually. Thirdly, they were asked to tell the meaning of the paragraph to their group. Fourth, students were asked to collaboratively organize the different paragraphs into a complete story and answer the comprehension questions together. Fifthly, they were asked to do intra-group reading assessments. Each group member read out a paragraph in turn to their group and each group member would assess her/his oral reading. And finally, one student from each group was picked, by drawing of lots, to represent their groups to attend the oral reading contest.

The teaching activity flow and materials used in the experimental group and the control group are identical except that the materials were built as e-version for the former. Each student in the experimental group was provided with a Tablet PC with a stylus and a headset, and the students of the control group were given identical printed reading materials to do the same activities as the experimental group.

Results

After the treatment finished, two respective observers first recorded the time spent on each target behavior. Then the Pearson product-moment correlation of the time proportion of the observed behaviors from the two copies of the recorded results was computed, and it was 0.908. The results of the in-class observation are shown in Table 1.

The numbers in Table 1 stand for the average time proportion which students spent on the following activities: (a) SWI (individual learning of sight word) and SWG (group learning of sight word); (b) PWI (individual learning of phonetic word) and PWG (group learning of phonetic word); (c) VR (vocabulary reviewing); (d) PR (paragraph reading); (e) ST (story telling); (f) SM (story map); (g) RC (reading comprehension); (h) IntraGPA (intra-group peer-assessment); and (i) InterGPA (inter-group peer-assessment). We found that there existed some problems that the control group had in group reading activities: *teacher-dependant*, *weak interdependent relationship*, *inefficient social interaction*, *inefficient peer-assessment*, and *absent-minded trait*. From the data shown in the lower part of Table 1, the reading behaviors of the experimental group contrast sharply with that of the control group. With the support of CAREER, the five problems found in the control group were significantly reduced. In comparison the time proportions used in learning-related and learning-unrelated behaviors, the chi-square analysis results show that the differences between the two groups are significant. It shows that in all the reading activities the frequencies of learning-related behaviors found in the experimental group are significantly higher than that in the control group. This obviously revealed that CAREER reduced the problems that the students of the control group had when doing individual or collaborative EFL reading activities and consequently benefited elementary EFL learners' collaborative learning with their peers.

Table 1: The reading behaviors of elementary EFL students and chi-square analysis results.

Group	Observed behaviors & Chi-square	Word Learning (%)				Text Reading (%)					
		SWI	SWG	PWI	PWG	VR	PR	ST	SM&RC	Intra GPA	Inter GPA
Control	Learning-related	62.4	46.1	59.4	50.8	62.4	72.2	77.2	59.6	30.6	75.5
	Learning-unrelated	37.6	53.9	40.6	49.2	37.6	27.8	22.8	40.4	69.4	24.5
Experimental	Learning-related	95.3	100.0	90.2	91.2	99.6	85.8	98.2	100.0	99.1	100.0
	Learning-unrelated	4.7	0.0	9.8	8.8	0.4	14.2	1.8	0.0	0.9	0.0
$\chi^2_{(1,1)}$		32.26*	73.97*	25.29*	38.85*	46.91*	5.91*	20.16*	57.00*	101.63*	28.27*

*p < .05.

Conclusion

It is supported by numerous researches that collaborative learning and peer-assisted learning are effective approaches to early reading instruction and learning. However, because of the reality of the elementary EFL environment there remains much to be explored about the possibility of mobile technology used in elementary EFL reading teaching and learning.

According to the results of observation, with the support of CAREER, elementary EFL learners were responsible for their reading tasks and actively involved in collaborative learning activities. Furthermore, because of the lack of basic abilities to accomplish the assigned missions, without the support of technology the students were unable to collaborate with their peers effectively. An opposite phenomenon was found when the mobile devices were involved in collaborative EFL reading activities. The use of mobile devices in collaborative EFL reading activities strengthened the low- and medium-ability students' essential abilities to do individual learning and consequently accomplished their assigned task. This successful opportunity of being responsible was led to the positive peer assisted and collaborative learning behaviors of the students. We can conclude that the proposed mobile reading system reduced the problems that the students had in a conventional collaborative learning environment, and the students were benefited by collaborating with each other with the support of mobile technology.

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A Learnable Content & Participation Analysis Toolkit for Assessing CSCL Learning Outcomes and Processes

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Abstract: In this paper, the authors first review the different kinds of analysis methods used by researchers to assess students' learning outcomes and processes to propose a categorization framework that can be applicable for assessment methods of CSCL discourse irrespective of the theoretical underpinning of the assessment method. A conceptual design for the construction of a suite of learnable content and participation analysis tools is proposed to provide intelligent support to analysis of online discourse. It is argued in this paper that the implementation of such a toolkit will facilitate collaboration and critical co-construction of knowledge about CSCL outcomes and processes among researchers. An example is also provided for the use of VINCA, a prototype for the toolkit, in comparing the cognitive engagement of two groups of students through text analysis.

Introduction

Since the launch of the World Wide Web in 1991, the use of CMC to support learning has taken flight and its importance as a field of study is increasing rapidly. There is a wide coverage of research interests and diverse theoretical and methodological approaches adopted in this burgeoning field of research. While there is no lack of descriptions and reviews of methods and indicators used to analyze online discourse data, the challenge of finding an appropriate set of instruments for specific purposes in CSCL research has not become easier. In fact, it is not even easy to compare and learn from the findings of research conducted by different researchers because of the great methodological diversities. *Computers & Education* published in 2006 a special section on methodological reviews of CSCL research that highlighted issues of accuracy, validity and reliability of the methods adopted (Valcke & Martens, 2006). Any attempt to make methodological categorizations for CSCL research is extremely difficult and many different approaches can be found in the literature (e.g. De Wever, Schellens, Valcke, & Van Keer, 2006; Dringus & Ellis, 2005; Mason, 1992; Rourke, Anderson, Garrison, & Archer, 2001; Strijbos, Martens, Prins, & Jochems, 2006). There are several key underlying characteristics of the researches that contribute to the methodological diversity and complexity of CSCL research: diversities in the researchers' theoretical underpinnings (De Wever, Schellens, Valcke, & Van Keer, 2006), their different research interests which span learning outcomes and learning processes of various kinds as well as mechanisms and models of collaborative learning. The greatest complexity relates to methodologies used in content analysis of discourse data. There is great diversity even in terms of the unit of analysis which can vary from a sentence to a paragraph, to a thematic unit, to a message or even a discourse (De Wever, Schellens, Valcke, & Van Keer, 2006; Strijbos, Martens, Prins, & Jochems, 2006) and reliability is a great challenge even for segmentation of analysis units.

This paper argues that there is a need for two kinds of tools to facilitate communication and co-construction of knowledge in the community of CSCL researchers: a common set of descriptors that researchers should provide to report on their methodologies and analyses results irrespective of their theoretical underpinnings; and a suite of learnable content and participation analysis tools to facilitate collaboration and critical co-construction of knowledge about CSCL. The next section proposes a framework for categorizing methods used to analyze the learning processes and learning outcomes in CSCL settings with illustrations from published research. This categorization framework will provide a set of descriptors that researchers could use when they report on their methodologies and analysis results. Based on this framework, this paper goes on to describe the conceptual design for a suite of analysis tools and extensible knowledge bases that would provide intelligent support to the researchers in analyzing learning processes and outcomes and indicators proposed. The suite of tools would be capable of "learning" such that the performance of the tools in its effectiveness as an intelligent support would improve through continuous enhancement of the knowledge base through use. The analysis results and the knowledge base derived from the use of such intelligent tools by different researchers can also be compared to facilitate comparison of different research approaches and methodologies. Finally, VINCA, a prototype for such a suite of tools will be briefly described.

Methods for Analyzing CSCL Processes & Outcomes: a Categorization Framework

To date, research in the area of CSCL may be underpinned by a variety of theoretical subscriptions. However, the purposes are relatively similar, and can be grouped into three categories based on the kind of research questions they ask. One category is the "*what"* questions – what have students learnt in this process. This could include cognitive, metacognitive and sociometacognitive outcomes. The second is those addressing the "*how*" questions and six dimensions can be identified in the published research in characterizing the CSCL process: participative, social, interactive, cognitive, metacognitive and sociometacognitive. The last category is those addressing the "*why*" questions to explore theoretical models of CSCL, how the process indicators may be related to the outcome indicators. Obviously, not only the *why* questions are strongly underpinned by the theoretical subscriptions of the researchers, but also the formulation of what counts as indicators for the *what* and *how* questions. On the other hand, irrespective of the theoretical underpinnings, the direct outputs from the analyses of discourse data, whether the methods adopted are quantitative or qualitative, are indicators for the learning outcomes and/or the learning processes (i.e. indicators for the *what* and *how* questions). Answers to the why questions are constructed by researchers on the basis of these two kinds of indicators. Furthermore, the same set of indicators may be used in different researches that adopt different theoretical perspectives and/or address different *why* questions.

Table 1. A categorization framework for methods of analyzing CSCL processes and outcomes illustrated with examples drawn from published research.

	Methods, indicators & examples of use		
What (learning outcomes)			
Cognitive	Quality of constructed knowledge using SOLO taxonomy (unistructural, multistructural, relational & extended abstract) (Veldhuis-Diermanse, 2002)	Critical thinking (+ve & -ve indicators for 10 categories: novelty, relevance, importance, linking ideas, justification, critical assessment, practical utility, etc.) (Newman, Johnson, Webb, & Cochrane, 1997)	
Cognitive/ Metacognitive	Critical thinking (+ve & -ve indicators for 4 categories: clarification, inference, judgment & strategies) (Bullen, 1998)	Categories of knowledge construction (new ideas, explanations & evaluation) (Veerman & Veldhuis-Diermanse, 2001)	
Sociometacognitive	Phase of knowledge co-construction (Gunawardena, Lowe, & Anderson, 1997)	Level of knowledge building (Law & Wong, 2003), (Law, 2005)	Level of discussion (higher-level, progressive & lower-level discussions) (Jarvela & Hakkinen, 2002)
How (learning processes)			
Participative	Level of participation (no. of messages) (Henri, 1992)	Density, intensity (Fahy, Crawford, & Ally, 2001)	
Social	Socially oriented statements (Henri, 1992)	Social presence (affective, interactive & cohesive responses) (Rourke, Anderson, Garrison, & Archer, 1999)	Stage of perspective taking of discussion (undifferentiated & egocentric, differentiated & subjective role-taking, self-reflective & reciprocal, 3rd person & mutual, in-septh & societal-symbolic) (Jarvela & Hakkinen, 2002)
Interactive	Social network analysis (Aviv, Erlich, Ravid, & Geva, 2003; Palonen & Hakkarainen, 2000)	Vertical & horizontal interactions (Zhu, 1996)	Kinds of content exchanged, directedness (vertical questioning, horizontal questioning, statements & supports, reflecting, scaffolding, references/ authorities) (Fahy, Crawford, & Ally, 2001)
Cognitive	Cognitive skills (clarification - elementary & in-depth, inference, judgment, strategies) (Henri, 1992)		
Metacognitive	Metacognitive knowledge (about person, task & strategies) and skills (evaluation, planning, regulation & self-awareness) (Henri, 1992)		
Sociometacognitive	Knowledge building developmental trajectory (Law & Wong, 2003) (Law, 2005)	Types of interactions (questions – information seeking or dialogue oriented, answers to provide information, information sharing, discussion, comment, reflection & scaffolding) (Zhu, 1996)	

It is argued here in this section that a categorization framework for analysis methods and indicators applicable to a diversity of CSCL learning theories and research interests would be profitable for facilitating comparison, collaboration and critical co-construction of knowledge within the CSCL community at the three levels of research questions listed above. Table 1 presents one suggested categorization framework with examples of methods and indicators drawn from published research. We find that in terms of assessing learning outcomes, three categories of outcomes were targeted in the literature, cognitive, metacognitive and socio-metacognitive. An example of a scheme for assessing cognitive outcomes in the learning of specific contents or concepts is one used in Veldhuis-Diermanse (2002) which adopted the SOLO taxonomy developed by Biggs & Collis (Biggs & Collis, 1982; Zhu, 1996). However, we find that most of the analysis schemes for cognitive outcomes in the published literature do not focus on the learning of content or concepts but on assessing students' critical thinking ability. Further, we find that some of the indicators such as evaluation, judgment and strategies were considered as cognitive by some researchers (e.g. Bullen, 1998; Veerman & Veldhuis-Diermanse, 2001) but as metacognitive by others (e.g. Henri, 1992). Instead of assessing the learning outcome of individuals in the collaborative process, some researchers were interested in assessing the socio-metacognitive ability of a collaborating group to co-construct knowledge through discourse (e.g. Gunawardena, Lowe, & Anderson, 1997; Jarvela & Hakkinen, 2002; Law, 2005; Law & Wong, 2003).

Sometimes, CSCL discourse was analyzed to examine the learning processes that took place through the online discourse. Six categories of indicators for the learning process can be identified in the literature: participative, social, interactive, cognitive, metacognitive and socio-metacognitive. Examples of participation indicators are levels of participation (Henri, 1992) and the density and intensity of the discussion (Fahy, Crawford, & Ally, 2001). Indicators for the social dimension of the discourse include a simple count of socially oriented statements (Henri, 1992), presence of affective, interactive and cohesive responses (Rourke, Anderson, Garrison, & Archer, 1999) and the stage of perspective taking of the discussion (Jarvela & Hakkinen, 2002). Examples of indicators for the interactivity of the CSCL discourse include social network analysis (Aviv, Erlich, Ravid, & Geva, 2003; Palonen & Hakkarainen, 2000), presence of vertical & horizontal interactions (Zhu, 1996), the kinds of content exchanged and directedness of the discourse (Fahy, Crawford, & Ally, 2001). Indicators for the cognitive, metacognitive and socio-metacognitive characteristics of the discourse can also be taken as indicators for the respective kinds of learning outcomes at the points when the process data was captured. In fact, the cognitive skills and metacognitive knowledge and skills as defined by Henri (1992) bears similarity to the critical thinking skills indicators of Bullen (1998) and categories of knowledge construction indicators of Veerman & Veldhuis-Diermanse (2001) developed for the assessment of learning outcomes. Law & Wong (2003) coded the socio-metacognitive characteristics of CSCL discourses as outcomes reached at various points in time to track the developmental trajectory of groups. These indicate that CSCL researchers generally perceive learning process characteristics as important outcomes.

Several researchers have commented on the different units of analysis from sentences to thematic units, paragraphs, messages and discourses being adopted by different researchers when analyzing CSCL discourse (De Wever, Schellens, Valcke, & Van Keer, 2006; Rourke, Anderson, Garrison, & Archer, 2001; Strijbos, Martens, Prins, & Jochems, 2006). We find such differences to exist not only between analysis schemes for different categories of indicators, but also within the same category. For example Bullen (1998) used a message while Newman, Webb & Cochrane (1995) used a thematic unit as the unit of analysis for coding critical thinking as cognitive learning outcomes. So far, it is not clear what impact such differences have on the analysis results and findings. It is even less clear what kind of similarities or differences exist between different sets of indicators of the same analysis category.

It is proposed here that researchers should clearly indicate, for each analysis method they use, a categorization for the indicators (i.e. which of the learning outcome(s) and learning process(es) are these indicators measuring) as well as the unit of analysis employed as a basic nomenclature for methodological description. Such nomenclature would already facilitate easier comparison of assessment schemes and indicators. More importantly, if there is an assessment toolkit which can document the operationalization of different analysis schemes indexed according to this nomenclature, this toolkit would be able to present comparisons of analysis outputs from different schemes and methods and facilitate more in-depth methodological comparisons and discussions. Furthermore, if the assessment toolkit can have built-in intelligence to support analysis of CSCL discourse based on the input coding schemes and be able to learn from coding actions of researchers to derive and improve on the coding rules, this will greatly facilitate the sharing of knowledge and skills in discourse analysis and hence contribute significantly to advancement in this research area.

Towards a unified toolset for analyzing CSCL

There are different tools currently used by CSCL researchers for analyzing online discourse. However, there are several important inadequacies in the tools that we have available currently that make discourse analysis a tedious, inefficient and often ineffective process:

1. The tools for different analyses are not integrated so that lots of time is wasted in transforming data into different formats for the different analyses.
2. Quantitative indicators have been criticized to be insufficient to reflect the quality of learning (Meyer, 2004) and content analysis is necessary to provide deeper understanding of the learning outcomes and processes. However, the only tools that are readily accessible to support content analysis are qualitative data analysis tools such as ATLAS.ti or N-vivo. These tools support the definition of coding schemes, search, creation of coding indices and exploration of different logical combinations of codes. However, the coding process itself is still largely manual and the main coding support is to highlight selected keywords in the discourse text.
3. The qualitative analysis tools themselves are incapable of learning so that no matter how much discourse analysis has been conducted by the tool, it would not make the coding process any less tedious for the coder.
4. While researchers can share the coding schemes they have developed, there is no tool that can provide a mechanism for different researchers to share their coding expertise.
5. Participation and interaction indicators and content analysis codes are generated separately by different tools, making it much more difficult to conduct a sequence of multiple analyses on the same set of data. Examples of profitable multiple analyses include generating the social network for discourse associated with selected discourse units that exhibit characteristics of specific cognitive processes, and displaying the coding labels for discourse units from group members with a high centrality index.
6. Coding of CSCL discourse is based on the interpretation of the discourse texts. Text mining techniques thus has the potential of providing the backbone for semi-intelligent coding tools but such technology has not been incorporated in the commonly available content analysis tools.

Matrinez et. al. (2006) proposed a mixed-evaluation framework and a software suite to study the participatory aspects of learning in CSCL. Their work represented advances in designing software suites that bridges social network analysis with qualitative and quantitative analysis of interview and survey data to overcome some of the conceptual and technical challenges mentioned above. Donmez et al. (2005) reported on the successful deployment of the TagHelper technology in the supporting autonmatic multidimensional categorical coding of CSCL data. The work reported here is an effort to build on and extend related work in the area. In the following section we describe the design of an analysis framework and a suite of analysis tools with extensible knowledge bases that would 1) provide intelligent support to the researchers in analyzing CSCL discourse using analyses schemes that fit within this proposed categorization framework for assessment methods and 2) support comparison of analyses using different sets of indicators.

A Conceptual Design for Learnable CSCL Assessment Tools

Based on the above reviews, we have developed a conceptual design for a suite of learnable content and participation analysis tools for use in CSCL research (see Figure 1). At the core of this toolkit is a coding schemes and coding rules database which keeps a well organized set of coding schemes indexed according to the categorization framework presented in Table 1 above. The database also keeps record of the coding rules that have been used by various researchers for the same coding scheme and the coding effectiveness for those rules. The toolkit contains modules that can learn from coding operations to continuously improve the coding rules, as well as provide mechanisms for users to compare and/or to merge the coding schemes and/or coding rules developed by different users. The toolkit contains the following key components:

Preparatory Components

These components are designed to transform discourse data collected from any CSCL platform into a form that can be processed by the analysis tools and to provide a mechanism for users to define the coding schemes and coding rules. There are three main preparatory components:

Data Preparation Component

This component allows the user to take discussion data from a number of popular CSCL platforms such as threaded discussion, Wiki and Knowledge Forum® and transform automatically into a standard relational database format. It will also allow the user to define the data structure from unspecified discussion platforms so that the appropriate data preparation process can be performed. The resulting *discussion record database* stores basic information such as author, date and time of post, the threaded discussion structure, message title and message body. There is also a discourse selection component to allow the user to select a subset of the discourse data for analysis according to the authors, the time period of the discourse took place, or other characteristics as desired.

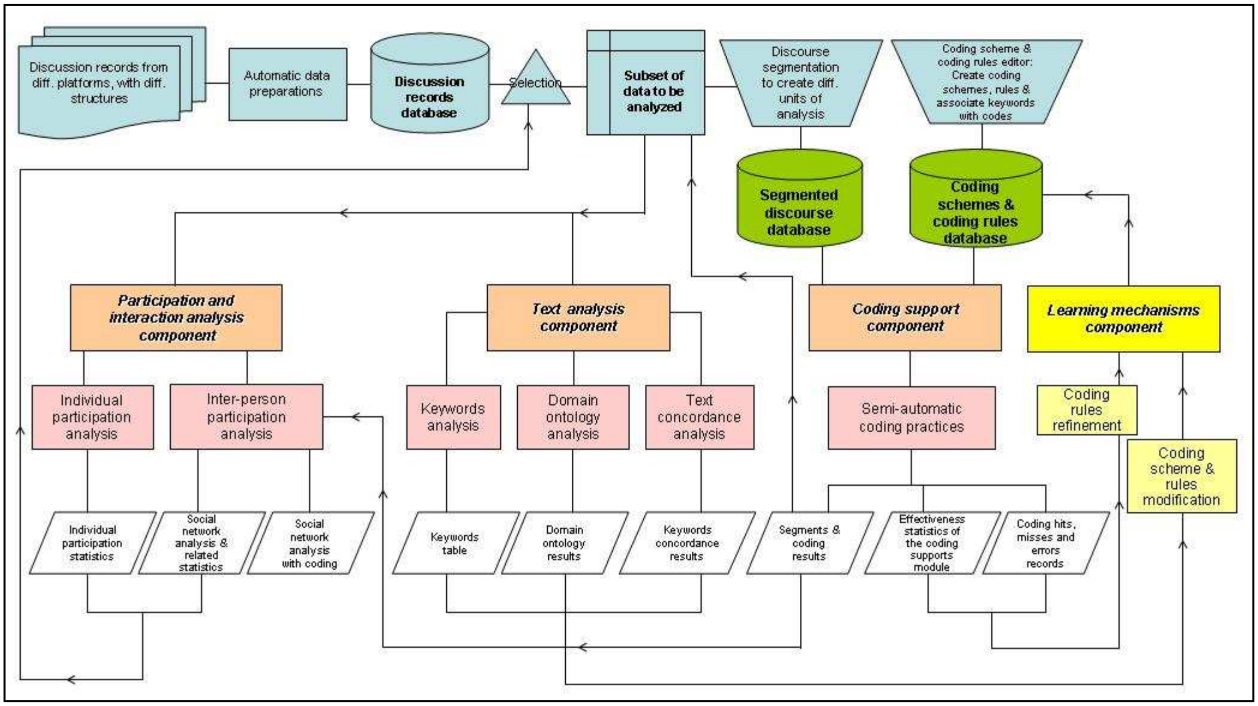

Figure 1. A conceptual design for a suite of learnable content and participation analysis tools for use in CSCL research.

Discourse Segmentation Component

This component allows the user to segment the discourse into appropriate units of discourse text for analysis. Thus the user can define the text units into sentences, paragraphs, themes, messages or any other units as the researcher finds appropriate. The output would be stored in the *segmented discourse database* ready for content analysis operations.

Coding Schemes and Coding Rules Editor

This editor will allow the user to create and store coding schemes and text pattern rules, which can be stored in the *coding schemes & coding rules database*. The coding schemes can have a hierarchical structure. Each code can also be associated with text patterns and other rules that user has found to have a high probability of being found in discourse text with that code.

Analysis Components

There are three main analysis components in this toolkit: the participation and interaction analysis component, the text analysis component and the coding support component. Each component may have several modules.

Participation and Interaction Analysis Component

In CSCL studies, researchers are interested in collecting user participation statistics at the individual and the interpersonal interaction levels. There are thus two modules in this component. The individual participation analysis module provides basic statistics on an individual's number of posts, replies, or number of keywords used in the discourse. For the inter-person participation analysis module, it can produce output data to generate social network analysis displays as well as statistics on interaction such as betweenness, centrality, clustering cohesion and so on. Using this same module, one should also be able to return participation and interaction analysis results for selected coded data, e.g. the individual participation statistics for discourse statistics showing high levels of critical thinking; or one could compare the centrality of the same group of participants for socially oriented v.s. inquiry oriented discourse.

Text Analysis Component

The modules in this component provide text analysis results that can help the user to formulate semantic analysis strategies on CSCL discourse data. One of the modules in this component performs keywords analysis. For any set of discourse data, this module can generate the list of keywords and key phrases used and the respective usage frequency. It can also compare the similarity between users in terms of their keywords usage. The second module performs domain ontology analysis. Very often, teachers and researchers are interested to know to what extend students' discussion overlaps with experts' or textbooks' conception of the focal content in the discussion. This module compares the domain ontology of the discourse with the concept map of the topic drawn by teachers or experts. Various statistics can be also be generated to reflect participants' performance, such as the similarity of the group's ideas when compared to the experts, individual members' contribution in terms of relevance of ideas, novelty of ideas, and extensiveness of ideas to the discourse. A third module in this component is the text concordancing module, which essentially allows the user to extract all text segments containing a keyword together with a user-specifiable length of text before and after the keyword. This is very useful since the semantic context of a piece of text cannot be clearly reflected by the presence of a single keyword or phrase. An example of how this module can be used to support further content analysis will be provided in the next section.

To summarize, the three types of analyses to be conducted by the modules in this text analysis component expose discourse dynamics at the semantic level. The outputs from the modules in this component in addition to being useful in themselves as a form of content analysis, can also help the user to generate insights to improve the analysis framework as well as the coding support component for conducting further content and participation analyses.

Coding Support Component

The coding support component supports researchers to conduct content analysis in more efficient ways through text mining of the discourse. As an intelligent tool, after the user has selected the coding scheme(s) to conduct coding, it should be able to provide aids, like highlighting discourse segments that match with the text patterns in the coding rules database and suggest appropriate codes for those segments. Since it is envisaged that there are limitations to the effectiveness of automatic coding based on the coding rules alone, the user will be able to decide which of the coding suggestions to accept. The coding hits and coding errors will be recorded. Further, the user may identify missed segments which should have been coded and add these codes in manually. These coding misses will also be recorded. After the coding process has been completed, the coded segments and the coding statistics (i.e. the frequency of occurrence of the various codes) will be generated for the user. This output can be exported in a database format for further quantitative and code co-location explorations. In addition, there are two more outputs from this process, the coding effectiveness statistics for each set of coding rules fired and three lists of discourse segments for the coding hits, coding errors and coding misses respectively in database format. These last two sets of outputs will be further processed by the learning mechanisms component. This is the core content analysis component in this suite of assessment tools and it is also potentially the most powerful one since it is improvable with increased use through the learning mechanisms component included in this toolkit. When the coding effectiveness of the coding rules improves, this component can be further developed to provide a training module for new coders. The coding results for the same set of discourse data by different coders can also be compared using this component to provide inter-coder reliability statistics as well.

An index of the coded discourse segments can also be fed back to the segmented discourse database to support further text selection criteria to allow more focused multi-step analysis of the CSCL discourse such as participation and interaction analysis for discourse having specific characteristics.

Learning Mechanisms Component

There are two modules in this component designed to refine and improve on the coding scheme and the coding rules database that form the knowledge base for the coding support component. One module is the coding rules refinement module which makes use of the hits, mistakes and misses lists of discourse segments and the coding effectiveness statistics for the rules associated with each code generated by the coding support component to improve on the coding rules. The second is the coding scheme and rules modification module which takes as its input the text analysis output and the user's instructions on the kinds of modifications desired. This module should be able to interpret keywords, keywords concordancing results, and results from domain ontology analysis.

Example Content Analyses Using VINCA, a Toolkit Prototype

The Visual INtelligent Content Analyzer (VINCA) is a CSCL discourse assessment tool jointly developed by the Centre for Information Technology in Education of the University of Hong Kong and the Knowledge Science and Engineering Institute of the Beijing Normal University to implement the design ideas described above. To date, a prototype for some of the preparatory components and the text analysis components have been implemented while the participation analysis and learning mechanism component has still to be developed (Huang & Li, 2006). This prototype is able to process textual records of discussion in both English and Chinese. In this section, we will give an example of how the text analysis component provides content analysis support that help to locate indicators of learning, irrespective of theoretical underpinnings, from online discussion logs. It is our intention that findings generated by the text analysis components will become one important source of information about students' learning that can be integrated with the participation analysis component to provide useful information to the teacher as well as learners about the progress of the discussion (Mochizuki et al. (2005) reported on an interesting study in which students' learning and interactions were influenced by the visualization of the proximity of their contribution to set keywords entered by the teacher).

Two groups matched in academic ability participated in an online knowledge building (Scardamalia & Bereiter, 2003) activity on the topic of "slimming" using Knowledge Forum® organized as part of their formal school curriculum. Three instruments were designed and administered to the two groups of students after they have completed the online activity to assess the impact of the activity on them. The three instruments were a weight-loss and nutrition concept test, a daily food intake inventory, and a weight-loss, exercise and body-image survey. It was found that the learning activity had significant impact on the understanding and attitudes on the students in one of the two groups (group A) but not on the other (group B) as measured by both the weight-loss and nutrition concept test scores and the self-image scores. However, group A had lower counts than group B on some commonly used quantitative indicators of discourse engagement: the total number of notes posted, the total number of threads, the length of entries and the total number of keywords in the messages recorded on Knowledge Forum®. VINCA was employed to see if it can provide some useful information on why such an outcome might come about. In particular, VINCA was used find out whether the two groups differed in the quality of the online learning discourse. The analysis provided evidence that group A in fact had a different engagement pattern to group B in the online discourse. This study was briefly reported in Law & the Learning Community Project Team (2006). Due to the limitation of space, only one of the analyses done using VINCA is reported below as an illustration of how this tool can be used to identify different levels of engagement. Detailed reporting on the whole study will be the subject of another paper.

To identify indicators of learning through the online discussion, VINCA's text analysis component started with retrieving all keywords and their counts from the whole discourse of the two groups of students. The aim is to identify keywords that may be indicative of students' cognitive and/or metacognitive engagement. From the keywords retrieved, three groups were identified to be useful as indicators of deep engagement that will likely lead to deep learning. One such group of keywords was indicative of *reflection* such as consider, think, know, believe, feel and agree (1). The second group was indicative of the author making a *claim* or a proposition, and included words such as in fact, therefore, moreover, explain and based on. A third group was words indicative of the author making a *query*, such as what, why, how and words used in questions. Table 2 presents the density of use of these 3 types of keywords in these two groups' discourses. It is apparent from the density of use of these 3 types of keywords that more cognitive engagement were present in group A's online discourse.

While the keywords were useful, it was also found that statements containing specific keywords per se may not actually be related to reflections, propositions or queries. Upon closer inspection, statements containing the personal pronoun "I" in the proximity of these three types of keywords were more likely to be statements that involved reflections, claims or queries. In order to increase validity in identifying indicators of learning from online discussion discourse, a two step identification process was designed. Firstly, concordance segments of text containing 20 words before and after the word "I" was extracted by the data preparation component in VINCA. These data subsets were then analyzed by the keywords analyzer in the text analysis component. The density of use of the 3 identified types of keywords in this selected set of text is also presented in Table 2. The result shows that group A again has a higher density in the use of these 3 types of keywords. Furthermore, the density difference between these two groups is even higher in this subset of text segments containing the personal pronoun "I".

To summarize, using the keywords analysis and text concordance analysis modules in VINCA, we have found quantitative difference in the density of keywords associated with deeper cognitive and metacognitive engagement identified through a two-step process between the two groups of students which suggested that group A was more engaged in the online discourse. This triangulates well with the finding that group A achieved better learning outcomes based on the weight-loss and nutrition concept test and self body-image survey. These results demonstrate that VINCA is potentially useful in providing useful indicators of learning engagement beyond simple quantitative measures of writing engagement such as the total number of keywords or word counts. We hope these would contribute to further discussions and developments in analyzing CSCL discourse.

Table 2 A comparison of the word count and word density for the three selected groups of keywords indicating reflection, explanation and query posted by the two groups of students in (a) the whole discourse, and (b) the concordanced text segments containing the personal pronoun "I",

		Word Count & word density for selected keywords in the whole discourse				**Word Count & word density for selected keywords in the concordanced text segments containing "I"**			
		Group A		**Group B**		**Group A**		**Group B**	
Number of keywords identified		1552		5396		738		2758	
Total number of occurrence for all keywords identified		4824		26546		1834		9986	
	Keywords	**Number of occurrence**	**Density per 1000 keywords occurrence**	**Number of occurrence**	**Density per 1000 keywords occurrence**	**Number of occurrence**	**Density per 1000 keywords occurrence**	**Number of occurrence**	**Density per 1000 keywords occurrence**
Reflection	認爲 Consider	19	*3.94*	34	*1.28*	15	*8.18*	10	*1.00*
	想 Think	5	*1.04*	27	*1.02*	4	*2.18*	19	*1.90*
	覺得 Feel	8	*1.66*	11	*0.41*	6	*3.27*	4	*0.40*
	相信 Believe	2	*0.41*	7	*0.26*	1	*0.55*	3	*0.30*
	知道 Know	2	*0.41*	7	*0.26*	2	*1.09*	2	*0.20*
	感到 Sense	2	*0.41*	7	*0.26*	2	*1.09*	2	*0.20*
	認同 Agree	4	*0.83*	1	*0.04*	3	*1.64*	1	*0.10*
	Category Total	**42**	***8.71***	**94**	***3.54***	**33**	***17.99***	**41**	***4.11***
	Density Diff.	***8.71-3.54 = 5.17***				***17.99-4.11 = 13.88***			
Claims	其實 In fact	15	*3.11*	17	*0.64*	9	*4.91*	9	*0.90*
	所以 Therefore	6	*1.24*	33	*1.24*	3	*1.64*	17	*1.70*
	而 Besides	18	*3.73*	96	*3.62*	13	*7.09*	43	*4.31*
	而且 Moreover	5	*1.04*	16	*0.60*	3	*1.64*	10	*1.00*
	解釋 Explain	1	*0.21*	1	*0.04*	0	*0.00*	1	*0.10*
	根據 Based on	4	*0.83*	10	*0.38*	1	*0.55*	2	*0.20*
	Category Total	**49**	***10.16***	**173**	***6.52***	**29**	***15.81***	**82**	***8.21***
	Density Diff.	***10.16-6.52 = 3.64***				***15.81-8.21 = 7.6***			
Queries	甚麼 What	5	*1.04*	0	*0.00*	3	*1.64*	0	*0.00*
	爲甚麼 Why	2	*0.41*	0	*0.00*	2	*1.09*	0	*0.00*
	怎樣 How	3	*0.62*	2	*0.08*	1	*0.55*	0	*0.00*
	如何 How to	1	*0.21*	7	*0.26*	0	*0.00*	4	*0.40*
	嗎 Question indicator	9	*1.87*	9	*0.34*	3	*1.64*	3	*0.30*
	呢 Question indicator	10	*2.07*	6	*0.23*	7	*3.82*	5	*0.50*
	Category Total	**30**	***6.22***	**24**	***0.90***	**16**	***8.72***	**12**	***1.20***
	Density Diff.	***6.22-0.9 = 5.32***				***8.72-1.2 = 7.52***			

Conclusion

In this paper, we have put forward a framework for categorizing methods used by CSCL researchers to analyze online discourse to assess students' learning outcomes and processes. Specifically, three types of outcomes (cognitive, metacognitive and socio-metacognitive) and six types of processes (participative, social, interactive, cognitive, metacognitive and socio-metacognitive) were identified. A proposal that this categorization together with the unit of analysis adopted should form a basic nomenclature for use by CSCL researchers in reporting on the assessment methodologies they use in analyzing CSCL discourse to facilitate easier methodological comparison and explorations. A conceptual design for a suite of learnable CSCL assessment tools that makes use of such a nomenclature is also presented. This proposed toolkit contains three analysis components, a participation and interaction analysis component, a text analysis component and a coding support component which will provide quantitative participation and interaction statistics, make intelligent coding suggestions for content analysis as well as iterative multi-method analysis. A very attractive feature of this set of tools is the availability of a coding schemes and coding rule database which forms the knowledge base for the content analysis components. The learnability is accomplished through the learning mechanisms component which contains modules that can modify and improve on the coding schemes and coding rules contained in the database. The learning mechanisms component contains a coding rules refinement module that can make improvements to the coding rules on the basis of the coding effectiveness of the coding support mechanism and a coding scheme and rules modification module which can make improvements on existing coding schemes and rules on the basis of the text analysis output. An example of how VINCA, a prototype developed on the basis of this conceptual design, helped to compare the levels of cognitive engagement for the online discourse from two groups matched in academic ability was also provided to illustrate the viability and usefulness of such assessment tools to generate analytical insights irrespective of the learning theory underpinning the CSCL design. It is expected that when the full suite of tools has been developed such that content analysis results can be analyzed and interpreted together with the results from participation and interaction analysis, we will be able to gain a much better understanding of what distinguishes a productive CSCL discourse and how that can be fostered. It will also contribute towards theory building about CSCL. as well as cont the suite to support mixed-method evaluation for evaluating different levels of engagement in CSCL based on the framework suggested. It is hoped that more researchers will be interested in developing and sharing assessment tools based on this conceptual design. This will facilitate collaboration and critical co-construction of knowledge about CSCL among researchers and improve our understanding of the outcomes and processes of online collaborative learning.

Endnotes

(1) The actual text written by the students were mostly in Chinese. The words listed here are just translations.

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Promoting Collaborative Learning in Higher Education: Design Principles for Hybrid Courses

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Abstract: This research explores the learning that took place in three hybrid university-level courses in education, which were designed according to three main design-principles: (a)engage learners in peer instruction, (b)involve learners in assessment processes, and (c)reuse student artifacts as resource for further learning. These principles were employed in the courses in different manners according to the goals, contents, and target audience in each of the courses. About 40 graduate, and 260 undergraduate students participated in the study. Data-sources included collaborative and personal artifacts in the courses' sites (wikis, forums, and documents created by teams or individuals), researchers' reflective journal, surveys and interviews. We focus on the first design-principle, and show how learning was promoted by features designed according to this principle in each of the courses. We recommend course-designers and instructors in higher-education to use the design-principles identified and developed in this research to foster meaningful learning in other web-based courses.

Introduction

Many higher education institutions and especially teacher education departments offer hybrid courses, which combine face-to-face with online teaching. Research shows that the combination of face to face with online instruction offers added value in supporting learner-centered and collaborative learning (e.g., Dean, Stahl, Sylwester, & Peat, 2001; Singh, 2003; Frank & Barzilai, 2004). Many of these studies indicate that in order for a hybrid course to encourage meaningful learning, it should be designed to support collaborative, learner-centered instruction, as well as embedded assessment for learning. The literature refers to learner centered teaching as one that supports learner knowledge-building by promoting higher order thinking skills, collaboration, product-construction, and reflection (Birenbaum, 2003; Cobb, 1996; Collison, Elbaum, Haavind, & Tinker 2000; Ewing & Miller, 2002; Mcloughlin & Luca, 2001; Rovai, 2000; Resnick, 1996). Embedded assessment refers to an ongoing process that emphasizes the integration of assessment into the instruction in order to support learning (Birenbaum, 2003; Birenbaum, Breuer, Cascallar, Dochy, Dori, Ridgway, & Wiesemes 2005; Dori, 2003; Mcloughlin & Luca, 2001; Liang & Kim, 2004).

In spite of the potential benefits in using hybrid courses for fostering meaningful learning, many professors use their course websites mainly for administration, for student accessibility to course materials, and for online submission of course-products. Learning in most cases remains traditional. The learners usually remain inactive; social interaction is usually limited, and learners typically are not involved in designing and carrying out the assessment. Consequently, most students are not provided with CSCL features that have been shown to encourage ownership on their own learning, foster their motivation, and improve their learning outcomes (Birenbaum, 2003; Dehoney & Reeves, 1999; Frank & Barzilai, 2004; Liang & Kim, 2004; Herrington, Reeves, & Oliver, 2005).

For pedagogy to be a leading factor in the use of technology (Salomon & Ben-Zvi, in press; Salomon & Perkins, 1996) instructors are required to do more than simply upload learning materials to the course website (Pea, 1994). They should carefully design features that engage learners in active learning, and that build on peer learning – a huge resource, usually neglected in traditional higher-education instruction (Herrington, Reeves, & Oliver, 2005). It is therefore important to formulate, via research, design principles for hybrid courses that support meaningful learning, and to provide examples that illustrate how these principles can be expressed as features in the design of hybrid courses. Defining such principles is especially important for guiding the design of university courses in field of education.

Students who experience these pedagogies in their own learning are most likely to use them in their future practice as instructors (Ewing & Miller, 2002).

In order for design principles to be accessible to instructors and course designers, Kali (Kali, 2006; Kali & Linn, in press) developed the Design Principles Database, as a public infrastructure to publish, connect, discuss, and review design ideas. The database is intended to bridge research and design in the area of educational technologies in a communicable and systematic manner, in order to enable designers to build on the successes and failures of others, rather than reinventing solutions that others have struggled to develop (Kali, 2006).

To respond to the challenges described above, the objectives of this research are to formulate design-principles that translate knowledge about constructivist and socio-cultural learning into general guidelines, design hybrid courses according to these principles, explore the effect of these courses on student learning, refine the principles, and contribute them to the Design Principles Database.

Context

Three hybrid courses that took place at the Department of Education in Technology and Science at the Technion were studied. The courses were designed and taught by the authors of this paper. A brief description of each course follows.

Course 1: Educational Philosophy

The objective of this course is to help undergraduate students construct an educational philosophy that would lead them as educators or as educational researchers. All the course meetings are conducted face-to-face. The course website guides students through group-activities, some conducted at class-meetings and some, designed to take place in between the meetings. Course activities are built around three dimensions: (1) A theoretical dimension, in which learners study relevant literature and discuss ideas in the area of educational philosophy, (2) a "school inquiry" dimension, in which learners analyze and assess one school they select from a given list of “interesting schools”, and (3) the "ideal school" dimension, in which learners apply knowledge gained through the other dimensions by designing and presenting a conceptual model of a school that represents their own educational perspectives.

Course 2: Learning and instruction in online environments

The course, designed for undergraduate and graduate students, focuses on theoretical and practical aspects in online learning and instruction. The first few weeks take place online and are devoted to community-building and discussion on students’ initial perceptions about online learning. In the second part of the course, students work in groups to build their own online "mini-course", which focuses on one issue about online learning and instruction which they specialize in (e.g., creating a sense of a community, the role of the teacher, supporting metacognitive processes, etc.). In the final part of the course students study each others’ mini-courses, taught by their peers, provide feedback to each other, and reflect on the whole process.

Course 3: Assessment of educational projects

The objective of the course is to provide graduate students with tools that will endow them with initial preparation as future assessment experts in science and technology education. The course includes face-to-face meetings and online forum discussions. The students read a diverse collection of articles on assessment, and each week a team of two students is in charge of posing questions and leading the online discussion. Each student is assessed via multidimensional assessment based on her/his contribution to the online forum discussion both as leader and participant, presenting the summary in class, including a comparison with two other articles, and a final project. The students are involved in developing the assessment criteria and their implementation in the course.

Methods

This study is part of a larger ongoing design-based research that studies the iterative design process of the three courses between the years 2004 to 2007. It explores how refinement of the various *features* comprising each course affected student learning in several enactments of these courses: 6

enactments of course 1, 2 enactments of course 2, and 3 enactments of course 3. A *feature* in this study refers to the design of any element that supports learning (e.g., an assignment that guides students in creating presentations of “a day in a student’s life” in their ideal school, in course 1; guidelines for using appropriate “voice and tone” when instructing an online course, in course 2; an assignment that scaffolds students in self-assessment, in course 3). The study reported here, is a snapshot of the larger study, focusing on the learning that took place in the *current* state of design of each of the courses. More specifically, we study how *different* features in each of the courses, which employ a *common* design principle affected student learning.

Unit of analysis and sample

The unit of analysis in this study is *a feature*; meaning the effect of a single feature in a single course on student learning. Since features in the courses were refined at various stages of the iterative design process, the sample-size used to collect data varies for each feature. The total number of students in all enactments of all courses is 312 (Educational philosophy, 229; Learning and instruction in online environments, 48; Assessment of educational projects, 35). However, the sample-size used to study features that were redesigned in the last enactment of a course, includes only students who learned the course in that specific run. Sample-size used to study other features, which stayed constant for several enactment of a course, and when no significant difference was found between student performances in these enactments, includes the total number of students who studied the course in these iterations. The sample-size for each piece of evidence is mentioned in the description of each outcome below.

Data sources

The main data source was the rich set of group and individual artifacts created by students in each of the courses. Some were created on the course site, using tools such as Wikis and forums, and others, such as Office documents were uploaded to the courses’ sites. Another important data source was a researchers’ reflective journal, in which we documented, after each lesson important events, discussions, and issues that came up in the enactments. The journal was written by one of the researchers and sent to the other researchers for adding comments and negotiating interpretations. To support our analysis of student learning from these two resources, we also conducted Lykert-type and open-ended surveys in each of the courses, which required student to reflect about their learning, using various features in the courses.

Data analysis

Using our “feature” unit of analysis, we sought to triangulate different types of evidence to support any claim we make about the effect of a feature in a course on student learning. For each feature we initially analyzed students’ understanding-performances (Gardner, 1991; Perkins, 1992) as expressed in artifacts they created when using this feature. We then came up with an assumption about the learning that took place using this feature. Finally, we sought corroborations to this assumption from other sources such as the journal and the surveys.

Findings

We first describe three of the major design principles that this study formalized (based on a literature review), refined, and contributed to the Design Principles Database. We then focus on the first principle, and show how learning was promoted by features designed according to this principle in each of the courses.

Principle 1: Engage learners in instruction of their peers

This principle calls for creating opportunities for students to serve as instructors of their peers. Playing the role of the instructor, whether the learners are a small group, or the whole class, and whether the instruction is done individually or in peer-teaching, has many advantages. Peer-instruction activities, when designed appropriately, can encourage students to deepen their understanding of contents, become more attentive to ideas brought up by peers, take responsibility about their own learning, enhance metacognitive skills, and increase motivation (Topping, 1996). Students who can reflect on their way of thinking and learning can set up learning goals and carry them out, choose appropriate learning strategies, and supervise their advancement towards achieving these goals (Linn & Hsi; 2000).

Principle 2: Reuse student artifacts as resource for learning

This principle advocates the use of artifacts developed by learners, as resources for further learning of their peers (Dillenbourg, 2002; Ronen et al., 2005). In this manner, the artifacts, created by individuals, or in groups, can support the learning of those who struggled to interpret and process a certain body of knowledge, as well as others, who can benefit from the products of this process (Bransford, Brown & Cocking, 1999). Scardamalia & Berieter (1994) argue that environments that support the development of a knowledge-building community, enable learners to share knowledge and artifacts, so that this knowledge becomes part of the environment, and other learners can build on and further advance this knowledge. They refer to such supports, in which the classroom community works to produce a collective product as second-order environments. They distinguish these environments from first order environments, in which the knowledge produced by learners is "merely a summary report of what is in individual minds".

Principle 3: Involve learners in assessment processes

This principle calls for involving learners in forming assessment criteria and in carrying out the embedded assessment in a course. Involving the learners in the objectives, design, and execution of the assessment encourages taking responsibility on the learning and improving student learning outcomes (Birenbaum, 2003; Dori, 2003; Mcloughlin & Luca, 2001). There are many ways to involve learners in assessment processes. These include designing activities in which students take part in developing assessment criteria, providing feedback to each other's artifacts, and participating in peer and self assessment. Many studies have shown that involving students in assessment is a powerful approach for leveraging learning processes in a variety of contexts (e.g., Falchikov, 2003; McConnell, 2002; Suthers, Toth, & Weiner, 1997; Topping, 1998; 2003). Learning outcomes from involving students in assessment processes are related to: (a) leveraging student understanding of assessment criteria, and thus supporting students in creating improved artifacts, (b) learning by reviewing peers' work, (c) consideration of a wide range of feedback, and (d) development of assessment skills (Ronen and Langley, 2004; Zariski, 1996; Dominick et al., 1997; Miller, 2003).

Course Name	Principles	Engage learners in instruction of their peers	Reuse student artifacts as resource for learning	Involve learners in assessment processes
Educational Philosophy	Features	Whole-class collaboratively constructed Wiki table to summarize jigsaw activity about philosophical approaches	Table summarizing philosophical approaches, constructed earlier by students, used for an analysis activity	Students develop criteria and participate in peer assessment of "ideal school" projects presented by their peers
Learning and instruction in online environments		Mini-course designed, developed & instructed online by students	Student participation in online mini courses developed and instructed by peers	Students evaluate the functioning of their peers as instructors of mini-courses
Assessment of educational projects		Theoretical topics in assessment taught by students via online and face to face discussions	Final projects based on contents gained in lessons instructed by peers	Multidimensional assessment of performance and assessors

Figure 1- Application of the three design principles via features in the three courses

The three design principles described above were the major principles that guided the design of the three courses in this study. Figure 1 illustrates how these principles were applied via different features in each of the courses. The features marked by the bold rectangle represent features that employ the design principle *"Engage learners in instruction of their peers"*. We describe these features in detail and provide evidence of their effect on learning below.

Feature 1: Whole-class collaboratively constructed Wiki table (Course 1)

This feature was introduced after the first enactment of the Educational Philosophy course, in which students claimed that they had difficulties in understanding three philosophical approaches that were studied in a Jigsaw activity. As a response, we supported learning from the this activity by designing this feature in three successive stages: (a) In the first stage students acquire knowledge in specialization groups – each individual takes part in a specialization group, which studies, via literature reading and discussion in a forum, one philosophical perspective (as in the original Jigsaw activity). (b) In the second stage all the students in the class collaboratively create a Wiki table from contributions of individuals and groups – at this stage the individuals return to their home-groups as experts in one perspective, and are responsible to teach this perspective to other members of their group. Each group is now responsible to fill the contents of one row in the Wiki table, which synthesizes one aspect in each of the perspectives. As a result, a whole class knowledge table, exemplified in Figure 2, is obtained. (c) In the third stage, students are invited to edit and refine contributions of their peers in the Wiki table. The Wiki table created in this feature serves as a resource for further learning (see Figure1: principle "Reuse student artifacts as resource for learning" as applied in Course 1).

	Philosophical Perspective 1: Essentialism	**Philosophical Perspective 2: Progressivism**	**Philosophical Perspective 3: Existentialism**	
Aspect 1 (of 6): Teacher's role	Contribution of expert student to Aspect 1	Contribution of expert student to Aspect 1	Contribution of expert student to Aspect 1	Contribution of group A to the class Product
Aspect 2 (of 6): Learner's role	Contribution of expert student to Aspect 2	Contribution of expert student to Aspect 2	Contribution of expert student to Aspect 2	Contribution of group B to the class Product
Aspect 3 (of 6): The School System	Contribution of expert student to Aspect 3	Contribution of expert student to Aspect 3	Contribution of expert student to Aspect 3	Contribution of group C to the class Product

Figure 2: Schematic representation of feature 1 -
Whole-class collaboratively constructed Wiki table

In order to examine the effect of this feature on student understanding of the three philosophical perspectives, we analyzed the quality of the collaborative Wiki tables created by students. The quality of the table represents students' ability to distinguish between nuances in each of the philosophical perspectives according to the various aspects, and therefore depicts their understanding of these perspectives. This was assessed by comparing the information in each of the table cells to a reference table created by the instructors. Since the collaborative table was a feature introduced at the second enactment of the Educational Philosophy course, and since no significant differences were found in the quality of these tables in the further enactments, we use here a sample of N=149 comprised of students from five enactments of the course. The analysis indicated that the information constructed collaboratively in each of these enactments was very similar to the reference table, leading to a mean value 95% (SD = 1.2%) for the five tables. This finding indicates that the process of learning a philosophical perspective in a specialization group, then having to teach this knowledge to peers in the home group, and having the responsibility of creating knowledge for the whole class in the collaborative Wiki table, supported student understanding of the contents.

Another outcome that indicates that the collaborative table was a productive support for student learning was received from the survey. A question about the collaborative Wiki table, which was added to the survey at the 6th enactment of the course, indicated that students (N=25) valued the use of this feature as one which contributed very much to their learning (4.0 in a scale of 1 to 5) (Figure 3). Interestingly, although this feature is comprised of literature reading, and online discussion of literature, these aspects, when examined individually, were rated lower (literature reading 3.8; online discussion of literature 3.5).

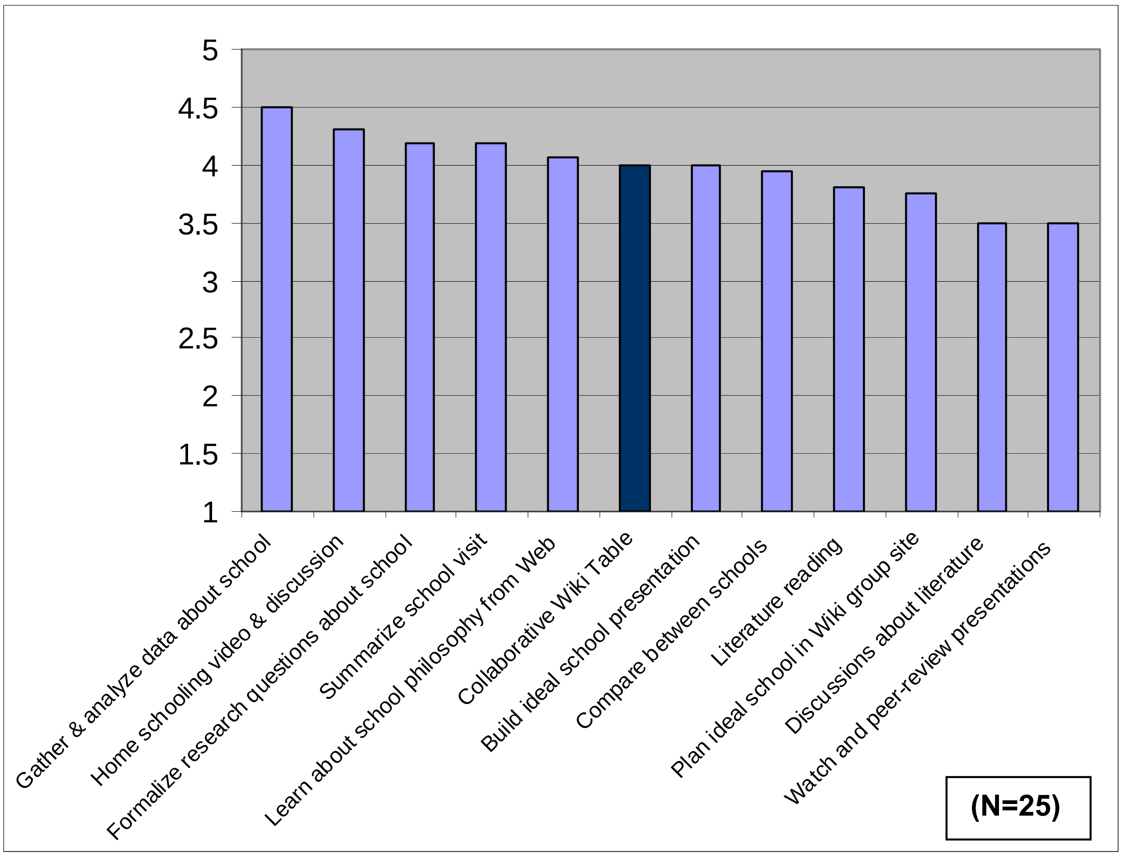

Figure 3: Average student rating of various course aspects in a scale of 1-5

Feature 2: Students design, develop, and instruct an online mini-course(Course 2)

This feature scaffolds students (working in groups) to design and develop their own two-week mini-course. Each group first learns the contents for their mini-course (issues in online learning and instruction) by reading and discussing relevant literature, then they design activities that implement these contents, and finally they teach (online) their mini-course to the rest of the class. The mini-courses created in this feature serve as a resource for further learning (see Figure1: principle "Reuse student artifacts as resource for learning" as applied in Course 2).

To evaluate the effect of the process of designing and teaching the mini-courses on student learning about theoretical and practical aspects in online instruction, we analyzed the process of designing the mini-courses and the final artifacts in three aspects: (a) students' *understanding of the contents* (as reflected in online discussion students participated in during the process of designing their mini-courses), (b) the *design of activities* (to what extent activities supported the contents and a socio-constructivist approach, were clear, and inviting, and (c) the *quality of instruction* of the courses (the extent to which instructors were attentive to their learners' emerging needs, in terms of understanding procedures, comprehension of contents, and collaboration with other learners).

Since the feature only changed slightly in the second enactment, and since no significant difference was found between the two enactments regarding the quality of mini-courses, we merged data from the two enactments of the course (total of N=48, number of groups = 15). Outcomes indicate that the mean values for the three aspects were as follows: *Understanding of contents* – 84% (SD=16%), *Design of activities* – 90% (SD=12%), and *Quality of instruction* – 88% (SD= 14%). The rather high variance can be explained by the fact that participants were a mix of undergraduate and graduate students. However, the high mean value, indicates that the quality of the mini-courses were high for the analyzed aspects. This indicates that the feature supported students' learning, especially of practical aspects in online learning and instruction.

These findings were strengthened by the analysis of the survey (N=48), which revealed that students perceived the mini-courses as a great contribution to their learning. In a scale of 1-5, the construct "Reading and discussing the literature in preparation for designing the mini-course" received a score of 4.8 (SD=0.4), "Design and development of the mini-course" 4.8 (SD=0.5), and "Instruction of the mini-course" 4.7 (SD=0.6).

Evidence to the type of learning that took place in this process can be found in responses to an general open-ended question in the survey. In these responses students explained in which manners the design of the mini-courses contributed to their learning. For instance, one student said "It was a great experience to instruct the mini-courses, we had to deal with many issues such as, what to do when the learning takes different directions than we planed, how do we support participation, how do we refer to posts in the forum which we don't agree with"

Feature 3: Theoretical topics in assessment taught by students (Course 3)

In this feature pairs of students are responsible to teach a topic about assessment to the rest of the class. They first study the topic, as the rest of the class does, from a pre-assigned list of articles. Then they lead an online discussion; they pose introductory questions in the forum, and are responsible for facilitating the discussion. Finally, they present a summary of the online discussion during a face to face meeting, and using additional references they find, they deepen the dialogue. Artifacts created in this activity (the online discussion, and the summary) serve as a resource for further learning by peers in final projects (see figure1: principle "Reuse student artifacts as resource for learning" as applied in Course 3) and for multidimensional assessment of performance (figure 1: principle "Involve learners in assessment processes" as applied in course 3).

To assess the impact of this feature on student learning, we examined the grades that were given by the instructors specifically for this feature. Two rubrics were used to provide these scores. The *criteria for leading the online discussion* included: (a) Posing questions that require higher order thinking skills; (b) Attentiveness to peers; (c) Processing and elaboration of the discussion by providing intermediate summaries; and d) Voice and tone that invite collaboration and foster a good atmosphere in the discussion.
The *criteria for leading the face to face discussion* included: (a) The quality of the online discussion summary; (b) Oral presentation of discussion and of further reading in an academic standard; and (c) Clarity, flow and originality in presentation.

We refer to the sample as N=35, comprised of graduate students in three enactments of the course (no significant differences were found between student performances in those enactments). The analysis indicates that grades for this specific feature were extremely high; Using the rubrics described above, the mean score for leading the online discussion was 98% (SD=3%), and 93% (SD=4.3%) for leading the face to face discussions. The score for the online component was provided by the instructor (10% of the final score in the course) and the score for the face to face component was provided by peer assessment (10% of the final grade). In order to express such high performances, students had to gain deep understanding and knowledge in the area assessment, and acquire leadership skills that are highly important for their careers.

Retrospective interviews, which were conducted about one to three years after the course, with students from all 3 iterations, indicate that students perceived the fact that they were required to take the role of an instructor in the course as a highly enriching learning experience. In many of the interviews the issue of responsibility and motivation, which were fostered by playing the instructor's role, were mentioned. For instance one student says "I new that in the moment of truth I will need to instruct part of the course. It gave me a great motivation… I felt that the challenge is greater than understanding; I also had to think how to make the contents interesting for others. Our responsibility for the success of the course was one that is higher than usually given in other graduate courses". The high motivation and responsibility brought students to become more critical and thus deepen their understanding of the contents. For instance, another student says "Serving as an instructor forced me to think deeper about the article, to ask myself questions and to find unresolved issues", or "Playing the role of the instructor is the thing I remember most from the course. I remember very well all the nuances of the contents that I was responsible for teaching. This is knowledge that I can retrieve from my mind at any relevant time". Another student noted that "the course provided me with inspiration and guidance about how to construct a new course for my high-school students in industry and management department". It is also important to note that having students play the role of the instructor involved putting them in a certain degree of anxiety, but that students saw this stress eventually as positive. For instance, a student says "This was a difficult period for me due to the high pressure I was in. I almost left the course, but was encouraged to stay, and today I am very thankful for that!"

Conclusions

The three design principles, articulated in this study i.e., *Engage learners in peer instruction, Involve learners in assessment processes, and Reuse student artifacts as resource for further learning,* were derived from known socio-constructivist approaches for instruction. Nonetheless, the large gap between the body of knowledge in the CSCL field, and the practices in higher education instruction requires that this knowledge would be articulated and published in a useful way for instructors, with examples of features that have been successful in several settings. The strength of the design principles described in this research is that although each principle was applied using different features in each course, one can see their major impact on the learning following the objectives set for each course: developing an educational perception (Educational philosophy), coping with challenges in online learning and instruction (Learning and instruction in online environment), and preparation of the learners as future assessment experts (Assessment of educational projects). It is important to note that the features described in this study are a consequence of an iterative design process, in which features were refined in several cycles in the larger research this study is part of. For instance, the idea to design the collaborative table using a Wiki technology emerged from findings showing that students did not feel ownership of the collaborative table. We assumed that enabling students to edit each other's cells would increase their ownership, an assumption which was later confirmed. It is our belief that the collection of design principles identified in this work and their publication in the Design Principles Database, along with links to the detailed examples of the features in the three courses, will constitute a resource that would enable instructors, and other course developers to apply these ideas in other hybrid courses. Yet, it is important to note that these principles cannot be used as recipes for designing courses. They gain their strength in being part of the Design Principles Database, in which design principles derived from other design-based research studies are contributed from the community.

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CSCL Interaction Analysis for Assessing Knowledge Building Outcomes: Method and Tool

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Abstract： Interaction analysis plays an important role in computer-supported collaborative learning. This paper proposes a multidimensional analysis framework to study the interaction and makes use of the quantitative analysis method to assess the collaborative knowledge building (CKB) outcomes at individual and group levels. A tool is developed that can support interaction analysis, text analysis, social network analysis and a combination of the above to show the differences of cognitive content and constructive level in terms of collaborative knowledge building. A case study of the interaction analysis via using the tool is presented.

Introduction

Computer-supported collaborative learning (CSCL) environments have been argued to foster collaborative knowledge construction. The process of collaborative learning can also be considered as a process of Collaborative Knowledge Building (CKB) (Stahl,G., 2003). In this process, learners construct shared understanding through collaborative interaction, and they are regarded as knowledge constructors rather than knowledge receivers. Therefore, analyzing the collaborative interaction between members can facilitate finding out the nature of knowledge building mechanism, which provides foundation for designing and developing CSCL environments.

So far, interaction analysis has draw close attention from many researchers. Generally, the interaction analysis methods usually fall into three levels. The first level takes the interaction as the communication to form relationship network, which emphasizes the relationship between members (Haythornthwaite, C., 1999; Nurmela, K.et al, 1999; Maarten ,L., 2002; Albrecht T.L.& Hall,B., 1991). The second level considers the interaction as the sequence combination of different speech acts, which pays more attention to the time structure relationship of communication information or activities. Hee-Jeon(2001)defines three categories (nine sub-categories) of interaction process and uses the sequence of speech acts to briefly describe the interaction. Harrer(2000)describes the interaction as a two-level conversational network. While Avouris(2003) proposes an Object-Oriented Collaboration Analysis Framework. A finer level of granularity than the speech act is focused on the ideational content. Porayska Pomsta analyzes the content based on categories of question. Clark(2005)assesses the interaction content by coding the conceptual quality of comment in Collaborative Learning (CL). By this way researchers can find more characteristics of CL at semantic level. However, there still lack an integrated method and tool to analyze CKB in CL synthetically. Furthermore, most of the researches usually use manual coding to conduct qualitative analysis of interaction content. However, qualitative manual coding involves subjective judgement and the reliability of dialogue analysis schemes remains a contentious issue (Pilkington,R., 2001).

A Multidimensional Analysis Framework to Study Interaction for Collaborative Knowledge Building

From the pedagogical viewpoint, collaborative learning should be assessed from multi-dimensions. Henri(1991), Newman(1995) analyze the performance of CSCL from group level. Stahl(2005) points out, group cognition should be centrally concerned by computer support for CKB. So it is important to regard group knowledge building level as the dimension of interaction analysis. On the other hand, according to the definition of basic elements of CL proposed by Johnson,D.W.& Johnson,R.T, (1989), individual duty is one of important factors that influence CL. This perspective shows that it is necessary to analyze group members' individual contributions in CL. Furthermore, many researches show that the relationship between group members has a great effect in CL. As Cartwright(1968)and Festinger (1950) presented, compared with the groups with loose cohesion, the members in the groups with intense cohesion have more satisfaction and happiness, and they are more inclined to participate actively, communicate frequently and seldom absent. Johnson(1989)even consider the positive interdependence as the first representative element of collaborative learning.

Therefore, by incorporating existing interaction analysis methods, we propose a multidimensional analysis framework to study interaction in terms of collaborative knowledge building (see Figure 1). The shadow ellipse represents the interaction analysis methods, which comprises three perspectives: Speech topics (i.e. the mentioned topics involved in the discussion), speech intention (i.e. the intention of speech act), and social network (i.e. member relationship and the degree of mutual support in a discussion group or community). The multi-method research framework lays the foundation to assess knowledge building outcomes with three criteria including "Group Knowledge Building Level", "Member Contribution" and "Member Mutual Support", shown as the ellipse nodes on outer triangle in Figure 1. The "Group Knowledge Building Level" indicates the collective knowledge building level of a group, and the "Member Contribution" reflects the individual performance in the collaborative learning process, while "Member Mutual Support" indicates the relationship between members as well as their speech similarities.

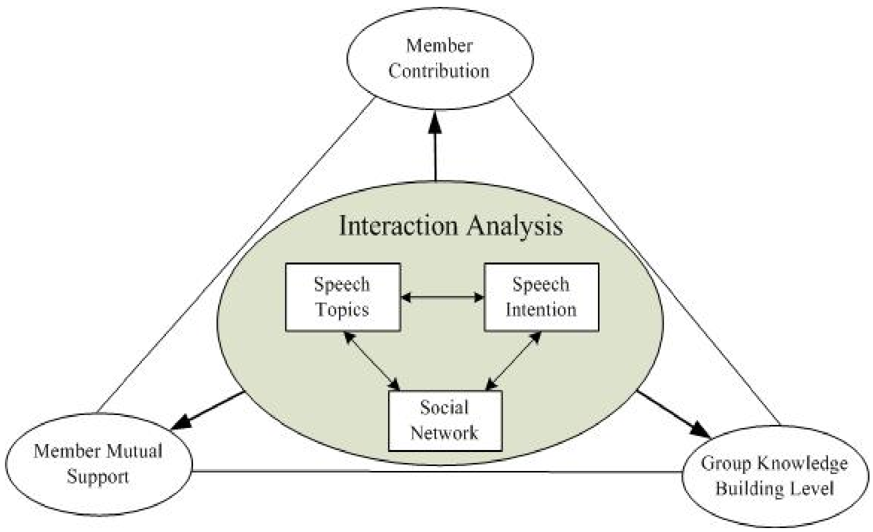


Figure 1. The Model of Integrated Interaction Analysis for CKB.

Computational Methods to Assess the Knowledge Building Outcomes

Group Knowledge Building Performance

Scardamalia&Bereiter(1994) propose there are three characteristics of the knowledge building community: "discussion related to the question promotes deeper understanding", "non-intensive and opening discussion" and " effective interaction " . Fisher(1993) 、 Mercer(1995) 、 Coelho(1994)consider effective interaction as "exploratory talk", whose characteristics is that participants communicate in a critical but constructive way. To summarize, "relevance to topic", "positive negotiation" and "common participation" are three important characteristics of knowledge building level of a group. So, we adopt "Group Topic Relevance", "Group Interactive Intention Level" and "Group Equilibrium" to evaluate group knowledge building level. Group Topic Relevance indicates the relevance of whole group's speeches to the discussion topic. Group interactive-intention level reflects the degree of positive argument or negotiation that are regarded as have higher interactive level to resolve cognitive conflict in a group. Group Equilibrium represent the consistency of member participation which can reveal whether every member participate in the group interaction positively. Based on the coding schema developed by Veldhuis-Diermanse (2002), with combination of the interaction analysis model (Gunawardena,L.&Anderson, 1997) and the model of collaborative knowledge building (Stahl,G., 2003), we bring forward a coding schema focusing on the learning processes. The coding schema includes five categories "sharing", "argument", "negotiation", "meta-cognitive", and "social greeting", in which there are nineteen speech acts in total. Taken the categories as the assessment criteria, a synthetic method based on Analytic Hierarchy Process (AHP) theory is applied to make quantitative analysis and evaluation of the individual contribution and group performance.

Definition 1: Group Interactive Intention Level $GI = W_{\max} \frac{\sum_{k=1}^{n} W_k M_k}{M}$

Where n is the number of the code of speech intention, W_k represents the weight assigned to each speech intention based on Analytic Hierarchy Process (AHP) theory, W_{max} equals to the maximum of W_k. M_k is the number of speeches of kth intention. M is the total number of speeches.

Definition 2: Group Topic Relevance $GR = \frac{GT}{T}$

Where T represents the total number of words in the domain vocabulary, GT represents how many words appeared in the groups' discourse are included in the domain vocabulary.

Definition 3: Group Equilibrium $GE = 1 - \frac{D}{D_{\max}} = 1 - \frac{D . S \sqrt{S-1}}{N(S-1)}$

Where D is the standard deviation of the speech numbers in a group, D_{max} is the max value of D. S is the number of members, N is the number of speeches.

Definition 4: Group Knowledge Building Level $GKBL = \alpha_1 GR + \alpha_2 \cdot GI + \alpha_3 \cdot GE$

Where $\alpha_1, \alpha_2, \alpha_3$ are the adjustment factors used to scale the importance of GR, GI and GE, respectively. It can be proved that the values of each factor are all between [0, 1].

Member Contributions to Collaborative Knowledge Building

Newman(1995) and Liu(2005) both consider the novelty of members' speeches and the extension of the topic to be discussed as the important criteria of evaluating the quality of interactive texts. Additionally, Albrecht&Hall(1991), Baldwin, Bedell & Johnson (1997), Haythornthwaite (1999) all think the centralization of members in a social network will influence the member's performance in a group. So we adopt "Relevance", "Novelty", "Extension", "Interactive Intention Level" and "Member Centralization" to assess member contributions.

Definition 5: Relevance $R_i = \frac{M_i}{M}$

Where M_i represents the number of topic words which are talked in the speeches of the ith member. M represents the total number of words in the topic vocabulary.

Definition 6: Novelty $V_i = V_{\max} \frac{P_i}{N}$

Where P_i represents the number of keywords mentioned for the first time by group member i. N represents the total number of keywords.

Definition 7: Extension $E_i = E_{\max} \frac{N_i}{N}$

Where N_i represents the number of keywords in each member's speeches. N represents the total number of keywords in the whole discussion speeches.

Definition 8: Interactive Intention Level $I_i = W_{\max} \sum_{k=1}^{n} (\frac{M_{ik}}{M_i} \times W_k)$

Where n is the number of the code of speech intention. W_k is the weight assigned to the kth speech act by using AHP approach. W_{max} equals to the maximum of W_k. M_{ik} indicates the number of ith member's speeches that are coded as kth speech act, M_i indicates the total number of speeches of ith member.

Definition 9: Member Centralization $C_i = \frac{ID_i + OD_i}{2S - 2}$

Where S is the number of student. ID_i indicates the number of ith member's in-degree of social network, OD_i indicates the number of ith member's out-degree of social network.

Definition 10: Member's Contribution $MC_i = \beta_1 R_i + \beta_2 V_i + \beta_3 E_i + \beta_4 I_i + \beta_5 C_i$

Where β_i (i=1, 2, 3, 4, 5) is the adjustment factor that represents the importance degree of each factor.

Group Member Mutual Support

Social Network Analysis (SNA) is usually used to find the relationship between members by counting the number of reply-messages between members, which doesn't consider the content of the speeches. However, we believe that the more similar of two members' speeches, the mutual support will be greater. As a complement, we take into account the content and intention of speech to augment the SNA. The algorithm of similarity is the same as the vector cosine method which is frequently used in calculating the document similarity in text mining technology.

Definition 11: Member's Speech Content Support

$$CS_{ij} = \frac{F_i \bullet F_j}{|F_i| \times |F_j|} = \frac{\sum_{k=1}^{N} F_{ik} \times F_{jk}}{\sqrt{(\sum_{k=1}^{N} F_{ik}^2)(\sum_{k=1}^{N} F_{jk}^2)}}$$

Where F_i represents the vector of word frequency in member i's speeches in the vector space model (VSM). F_j represents the vector of word frequency of keywords in member j's speeches. F_{ik} represents the word frequency of the kth keyword in the speeches of the ith user. F_{jk} represents the word frequency of the kth keyword in the speeches of the jth user. N represents the total number of keywords. Therefore, we can obtain the matrix of the degree of member's support CS, which represents the degree of mutual support among group members.

Definition 12: Member's Speech Intention Support $$IS_{ij} = W_{\max} \frac{\sum_{k=1}^{n} W_k M_{ijk}}{M_{ij}}$$

Where n is the number of the code of speech intention. W_k is the weight assigned to the kth speech act by using AHP approach, W_{max} equals to the maximum of W_k. M_{ijk} indicates the number of ith member's speeches which reply the jth member and are coded as kth speech intention. M_{ij} indicates the total number of speeches of ith member who reply to the jth member. Above factors can be proved that their values are between [0, 1].

Implementing a Tool to Support Interaction Analysis

We have developed a tool VINCA (Visual Intelligent Content Analyzer) with C# language to support interaction analysis. It is implemented by using C/S architecture and can be installed stand-alone or support the online downloading of the forum text from CSCL platform (currently support WebCL platform http://www.webcl.netc.cn) to conduct analysis. The tool provides a plug-in interface allowing for flexible addition of more modules. VINCA can support coding analysis, text analysis, social network analysis and a combination of the above to assess the CKB outcomes for showing the differences of cognitive content and constructive level in terms of collaborative knowledge building. It is worth to note that VINCA distinguishes from other similar tools with three features: 1) Learnable semi-automatic coding support; 2) Text Analysis for traditional and simplified Chinese; 3) Compute content similarity of user speech. Herein we give several snapshots of the VINCA interface (see Figure 2, 3, 4). In brief, VINCA mainly has the following functions.

- Flexible data source selecting. VINCA can automatically parse the discourse data in the HTML format and then store in the database. Currently it supports the data format of Knowledge Forum (http://www.knowledgeforum.com/) and WebCL (http://www.webcl.net.cn) platform. Users can select the specific data sources according to his specified filtering variables, such as speakers, keywords, time, coding, or the combination of the above variables.
- Semi-automatic coding aids. Besides supporting the users to manually code, VINCA can learn the coding hint by using machine learning method. In this way, VINCA can automatically discover the code hint, highlight it and associate it with recommended codes.
- Keywords extraction & frequency counting. VINCA fulfills the task of extracting meaningful keywords and counting their frequency. As complement, uses can specify domain lexicon or exclusive keywords list to focus on some specific keywords or exclude some useless keywords.
- Concordance (keywords in context). Users can click the keywords to view the context in which they appear.
- Group & individual performance analysis. By means of the above methods, VINCA computes the assessment

indicators for evaluating the group and members' contribution and performance.

- Data export for SNA. VINCA provides several output data sets for augmented social network analysis, such as export relation matrix, export coding result, export coding matrix, content similarity matrix, etc.

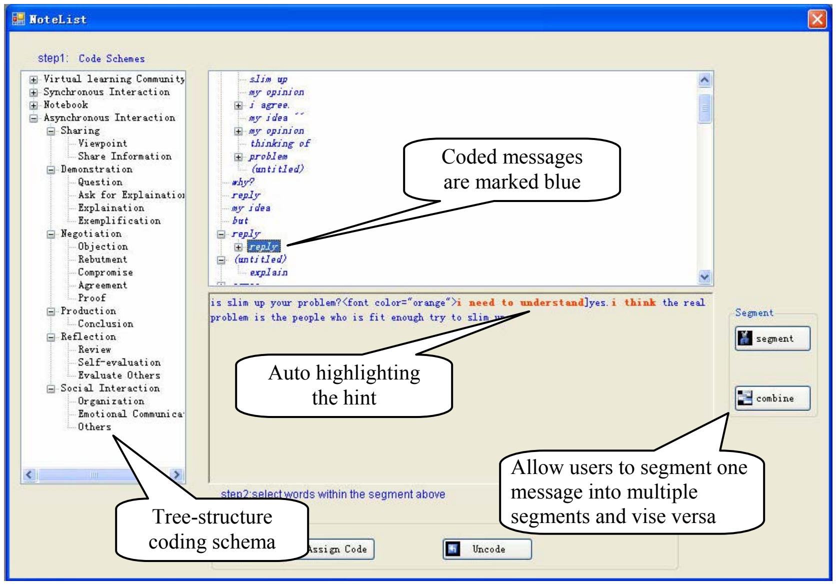


Figure 2. Semi-automatic Coding

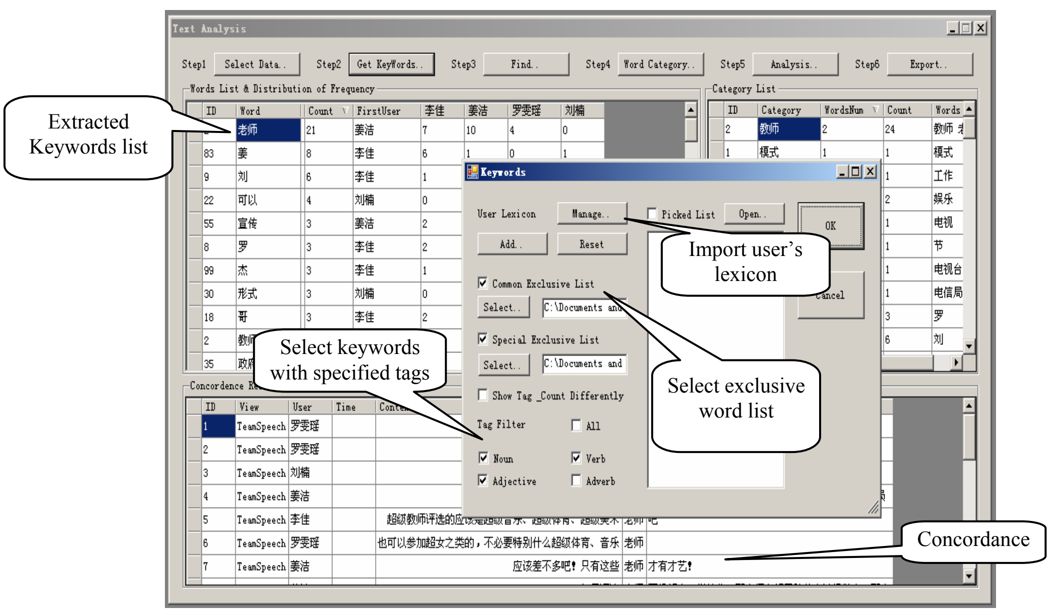


Figure 3. The interface to view the keyword extraction and concordance.

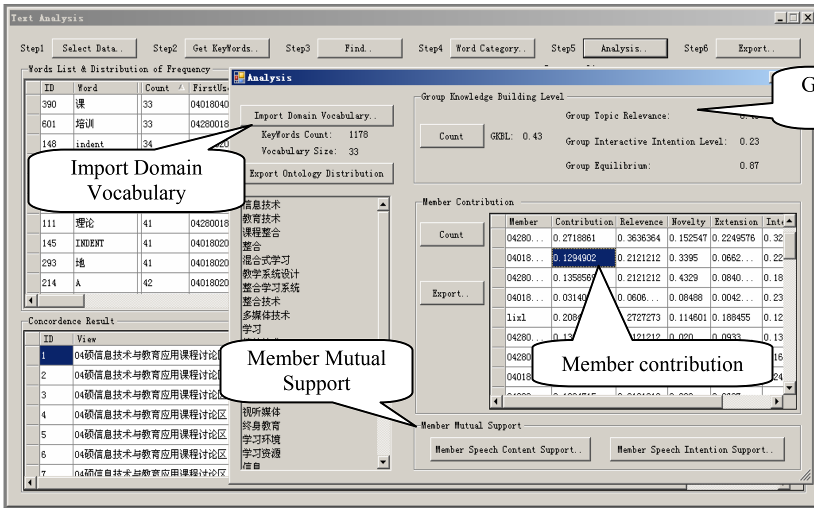


Figure 4. The interface displaying the computerized group and individual performance.

A Case Study of Interaction Analysis

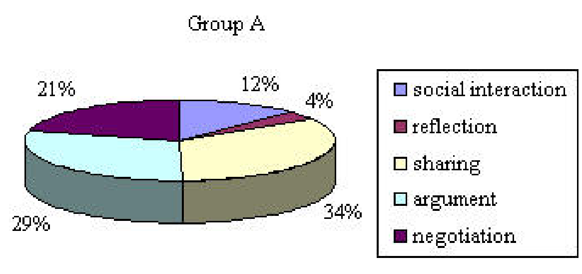
We have developed an e-learning platform WebCL (available at http://www.webcl.net.cn/) that has been used in more than twenty universities and high schools, and the total number of registered users exceeds 10000. VINCA can be installed stand-alone and support the online downloading of the forum text from WebCL to conduct analysis. We chose two sets of CSCL discourse data of two classes of graduate students enrolled in the same course "Information Technology and Educational Application". The two classes are respectively taken as group A (number of total students is 47) and group B (number of total students is 87). With the assistance of VINCA, we followed a four-step process to conduct the comparison analysis in terms of collaborative knowledge building, including group knowledge building level, member contribution and member mutual support. The process comprises: 1) Import the data in HTML format into VINCA. 2) With the semi-auto coding support of VINCA, coded all the discussion messages of the two groups. 3) VINCA was used to generate the frequencies of meaningful keywords found in the discussion discourse, and extraction of text in close proximity to selected keywords using concordance technique. 4) Use VINCA to export the data for SNA.

Table 1: Code scheme and weight.

Code	Weight	Sub-code	Weight		Code	Weight	Sub-code	Weight
Social Interaction	0.040	Organization(OR)	0.017		Negotiation	0.544	Objection(OB)	0.030
		Others(OT)	0.002				Rebutment(RB)	0.077
		Emotional Communication(EC)	0.005				Compromise(CO)	0.144
Sharing	0.109	Viewpoint(VP)	0.048				Conclusion(CL)	0.237
		Suggestion(SU)	0.048				Agreement(AG)	0.033
		Share Information(SI)	0.024				Proof(PR)	0.077
Argument	0.231	Question(QU)	0.030		Reflection	0.077	Review(RE)	0.033
		Ask for Explaination(AE)	0.012				Self-evaluation(SE)	0.007
		Explaination(EX)	0.063				Evaluate Others(EO)	0.013
		Exemplification(EF)	0.100					

Group Knowledge Building Level

The teacher constructed a domain vocabulary of the course that contains 35 words, such as “information technology”, “educational technology”, etc. As the above-mentioned method explained, this domain vocabulary is used to compute the relevance of members’ speeches. To determine our inter-coder reliability we firstly, for each coded message, checked to see if the codes assigned by the two coders referred to the same parts of the message (i.e. the same units of meaning). Secondly, we checked to see if the two coders had assigned the same codes to each unit. Based on a 10% sample of all the messages coded by the two researchers, the value of Cohen’s Kappa exceeds 0.7 for 16 categories. Afterwards, based on the AHP method, we assigned the weights to each code indicating the importance of each code in terms of cooperative knowledge building (C.I.<0.1)(see Table 1). According to above methods, all the messages of two groups (Group A: 237 messages; Group B: 577 messages) are coded. Figure 5, 6, 7 show the coding results in detail, which show that most of the Group B’s messages are coded as “sharing”(48%) and the percentage of messages coded as argument and negotiation are 22% and 10%. In contrast, 29% messages of Group A are coded as “argument” and 21% messages of Group A are coded as “negotiation”. This suggests the speeches of Group A reflect more cognitive conflicts that can foster the collaborative knowledge advance. Based on the statistical result, Figure 8 shows the computerized indictors of group knowledge building level.



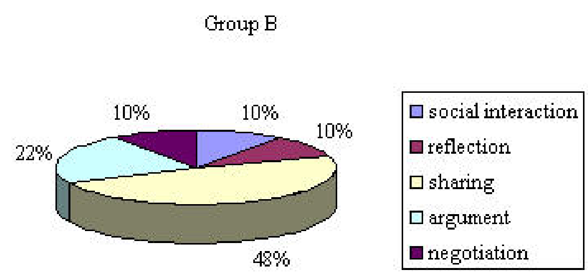
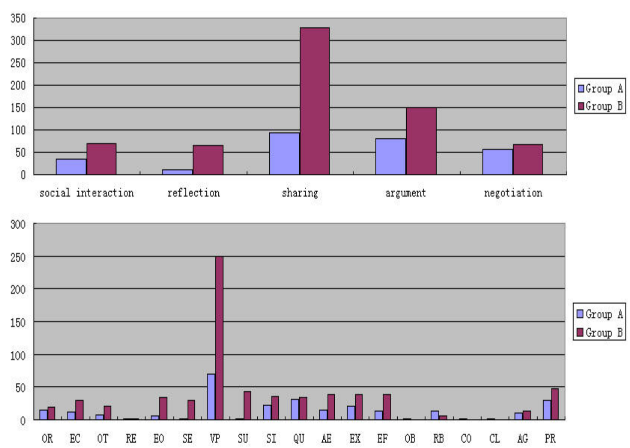


Figure 5. Coding result of Group A.

Figure 6. Coding result of Group B.



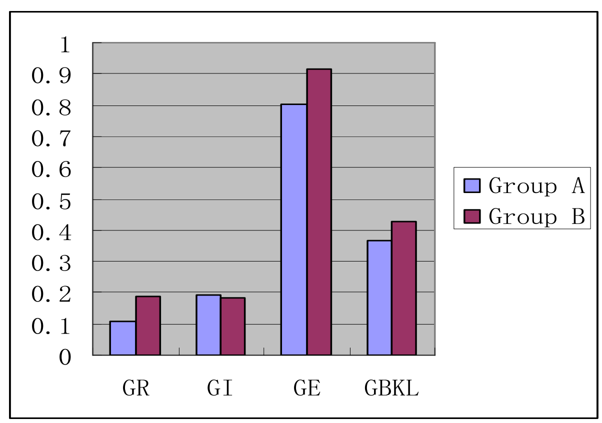


Figure 7. Coding result comparison of group A and group B.

Figure 8. Group knowledge building

Member Contribution

Based on the above methods, we compute the member contribution in terms of five dimensions (Relevance, Novelty, Extension, Centric, Interactive intention). Figure 9 gives an illustrative sample of two members’ contribution in the same class. From the figure, we can see that the extension level of two members is approximate, but member one (Student Number: 50280280203) performs better than member two (Student Number: 50280280153) in terms of relevance, novelty, centralization and interactive intention. This indicates the total contribution of member one is higher than member two.

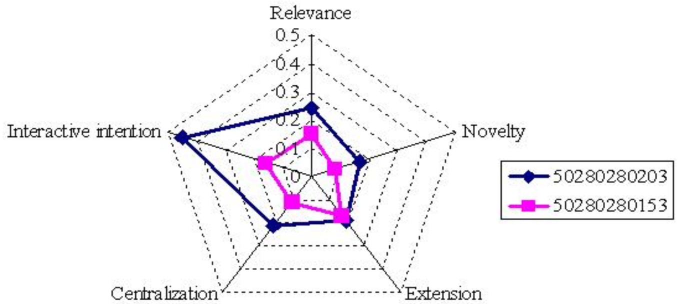


Figure 9. Illustrative sample of member contribution.

Member Mutual Support

By analyzing the reply-to relationship of messages and coding results, we drew the social network and interactive intention network of twenty members selected at random, as shown in the figure 10 and figure 11, respectively. Figure 10 illustrates the usual reply-to relationship between members. Figure 11 is an interaction intention network figure where the edge means the members' interaction intention. The wider the edge is, the higher interaction intention of the member is. For example, we discovered that the member (SN: 50280280203) not only plays a centric role, but his level of interaction intention is higher. In contrast, the level of interaction intention of member (SN: 50280280273) is lower. It suggests that this member provides more information for sharing rather than argue or negotiate with other members.

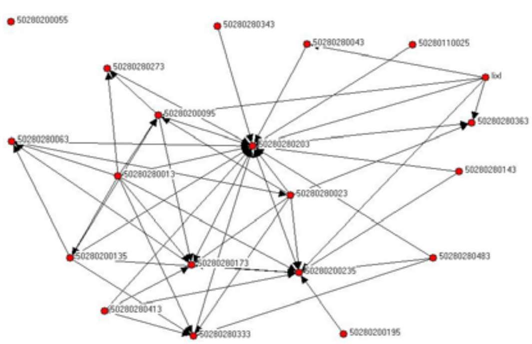


Figure 10. Social network

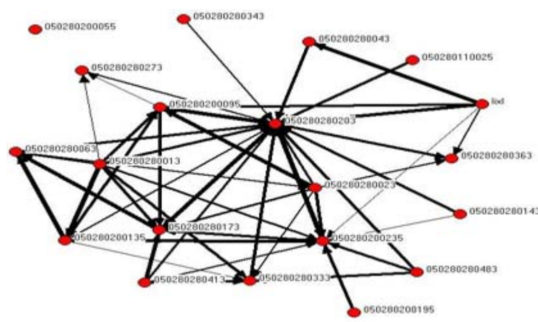


Figure 11. Interactive intention network

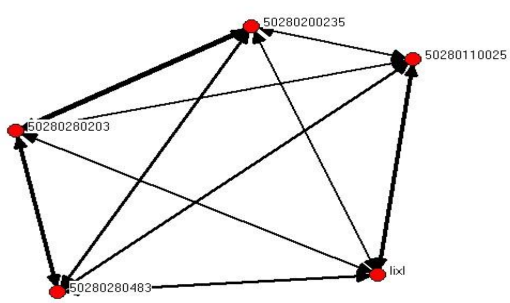


Figure 12. Grid-mode Social Network

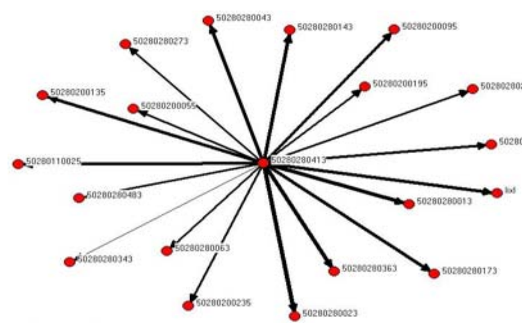


Figure 13. Asterisk-mode social network

Moreover, the members' speech similarity matrix was exported with VINCA and we drew two-mode figures to intuitively show the members' mutual support in terms of content similarity. In the figure, the edge means the degree of speech similarity of two members. The wider the edge is, the higher similarity of two members' speeches is. Figure 12 is the grid-mode social network that gives an illustrative example of five members' mutual support. As the figure shows, the edges pointing to the member (SN: 50280280203) are wider than that of other members. It suggests that his speech drew extensive attention. Likewise, the member (SN: lixl) is another central member in the group. However, the content similarity of the two members' speeches is relatively low. From this, we can see that the different speeches presented by the two members both draw much attention from others. Figure 13 is the asterisk-mode social network that shows the content support between a member (SN: 50280280413) and other 19 members. From the figure, we can see that the speech content similarity between him and other members is high except one member (SN: 50280280343).

Conclusion

Qualitative analysis method is widely adopted to analyze collaborative interaction. By contrast, this paper explores the quantitative method to analyze the collaborative interaction, attempting to calculate and summarize the interaction characteristics for assessing the collaborative knowledge building outcomes. We have developed a multi-method research framework to study collaborative learning processes by making use of social network analysis (SNA), content analysis (CA) and text analysis technology to assess group knowledge building level, member contribution and member mutual support. We have developed a tool to assist the interaction analysis, and conducted a case study with the tool on two sets of CSCL discourse data from two comparable classes. The results show the differences of cognitive content and constructive level between two classes, and provide suggestive findings for assessing the knowledge building outcomes at individual and group level.

Further investigations are needed to analyze the various roles the participants play in the collaborative learning, and to examine how individual and collective knowledge advances intertwined. Meanwhile, apply the tool in more practical education settings and to improve it according to the feedback from researchers and teachers.

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Implementation of the Scrabble Game on the Mobile Devices to Increase English Vocabulary Acquisition

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Abstract: The Scrabble Game redesigned on the mobile devices has been implemented. through this game to facilitate English vocabulary acquisition of the elementary school students with group collaborative and competitive learning activities. We reviewed literature related to collaborative, competition and language learning. Moreover, the concept of game design and its system architecture have been presented. It is expected that research findings in actual English learning contexts will further share in the near future.

Introduction

Collaborative learning (CL) focuses on active learners of knowledge, and emphasizes the learning process (Slavin, 1990) and learning outcomes. Students will enhance cognitive learning from memory through the interaction and coordination between groups (Zurita & Nussbaum, 2004). Face-to-face CL activities may probably come up with disagreement or different points of view, so group members need to cultivate abilities for communication and negotiation. The clash and stimulation between the groups would encourage students to work for good performances. In the process of CL, it can be more convenient by using mobile devices. Mobility has increased dramatically with the portability which conveniences interactions between members and enables immediately exchange of different thoughts with appropriate amendments and responses. In addition, a shared visual space is essential for collaborative activities because it facilitates grounding and communication (Kraut, Gergle, & Fussell, 2002). Studies (Inkpen, et al., 1995) show that compared with single-operator learning, the group collaboration learning would be a positive influence on performance of more effective cooperation for the achievement and joys. Good competitive interaction between groups is helpful to challenge learning task and enhance the sense of solving problems and joy.

Language and thinking are interrelated and affect one another. Language comprehension is relevant to vocabulary development abilities (Robert, 2003). The emphasis on language learning is meaningful to communication and applications (Carol, 2001). Accumulating vocabulary is one of the bases of language learning. It strains to memorize words; the effect is not only less fun but reducing learning motions. Therefore, the goal of this study is to take vocabulary learning by the group collaboration and competition model to inspire their motivation and learning achievement. The best strategy is discussing collaboratively. Crossword puzzle has generally been assigned for students' alternative self-Access activities and instruments by teachers and been considered and provided have appreciable potential. (Wise, 2001; Franklin et al., 2003; Jones, 2003). However, the traditional crossword puzzle restricts students' answers with the only one correct solution and is lack of interactivity in the class for group to discuss and learning collaboratively.

Generally, competition has always been regarded as a contrast of collaboration. However, the concept we propose in this game is to design a competition of the two group members which conducts them to correct, analyze, study, discuss and doubt each other's answer. In a competitive game-learning environment, students are motivated to make efforts to go for better performance (Chang, Yang, & Yu, 2003). This is the way we regard as an important part in CL. In this paper, based on the idea to improve crossword puzzle, we redesign the Scrabble game, a popular word game and board game in which 2 to 4 players score points by forming words from individual lettered tiles on a 15-by-15 game board. We redesigned the activity which students could build their own English vocabulary map especially through a competition model to encourage them accomplishing the motivational CL activity between groups. Furthermore, we implemented the activity by applied to portable device (especially to PDA) in an online collaborative learning environment based on Tuple Spaces system which was developed by SRI International. The motivation of the game is not only to encourage students to memory much more vocabularies, but also try to make student analyze and doubt opponent's words through a competitive way. Students can view the other group's results through the PDA and compare with each other to learn more vocabularies through the game. We expect this game to raise students' motivation on English learning and discussion between groups.

Game Design

In simple terms, the Scrabble game is an English cooperative learning game and an activity designed through competition of building the vocabulary by two groups.

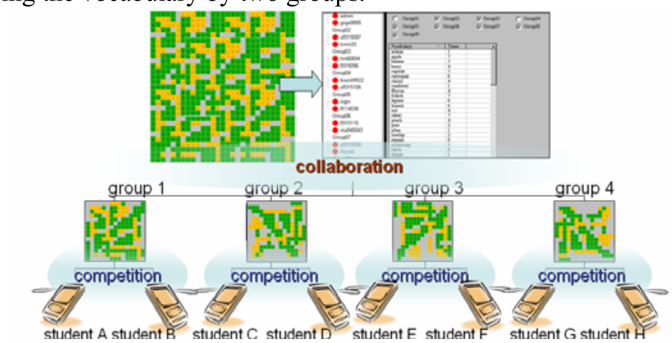

Figure 1. The Collaborative Mode of the Scrabble Game.

To win the game, participants of each group must try to fill in the vocabulary map and cover the opponent's letters with words separated by letters in each grid horizontally or vertically. Between group, students can analyze words oblong map which created up by the other groups. This game inspires participants to think, analyze, generalize and draw a conclusion map collecting the thoughts and the other group in a systematic manner.

The game is proceeding as following steps:

1. Prior to the game, the teacher can assign the theme of each round (food, transportation, travel, etc.) and put one or more than one character. Each character should put in each grid.
2. Students in the same group take turns to put word which related with the theme vertically or horizontally in the map to cover the exited letter or letters in the map. If you cover opponent's letter, you get the gird of letter.
3. Students take turns to build up the map with word will be restricted in few seconds which controlled by teacher. Student not building in time will lose the opportunity to answer at once and be changed by opponent.
4. Students criticize and doubt of the opponent's word if the word dose not fit the theme.
5. In the limited time and range, the one who gets the more grids than the other wins the game.

System architecture and implementation

The student client interface was divided into the map, letter area, input area and indication area. Students can input word into the input area by hit the letters in the letter area. Then students can select the word direction (vertical/horizontal) in the input area. The word can be drag to the suitable location on map areas. In indication area will show information about the two sides scores, each of the remaining time. When feeling puzzle with opponent's word, students can propose doubt by pressing the question button in the indication area.

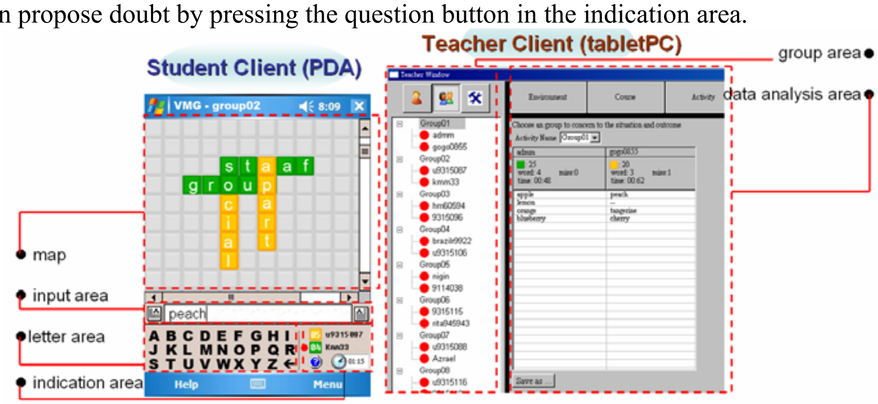

Figure 2. the Scrabble Game Client Interface

Teacher client interface was divided into group area and data analysis area. In group area, teachers can divide students into groups. In data analysis area, teacher can concern the situation and result of each group while the activity is processing or over, and teacher can collect all the vocabulary results of all groups in a table and share to each student's client screen to share the experience of the game to. The system also can track the progress of participants and offer the data to teachers for use of students' vocabulary research.

Further Work

In this paper, the new concept "collaboration" between members and groups has been introduced. Whereas current system in progress is based on system and activity feedback, we believe that this concept will yield some significant findings and well appreciated by the students.

To be further explored, further and more particular investigation is needed to evaluate how the Scrabble game changes affect students' learning process and how to achieve its anticipated capabilities and facilitate students' learning effective compared with the other traditional English learning activity. Furthermore, this conception could be implemented by more games and activities in collaborative learning to raise students' motivation to study English and discussion between groups. Finally, through the Scrabble game to encourage students' motivation of learning, we could implement more application focused on active learning and self-regulatory activity of group.

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Studying the Effects of Scripts and Technology on Cooperative Learning

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Abstract: The experimental study investigated the effects of a cooperation script with technology and face-to-face forms of group learning. The results revealed that the use of scripted cooperation and the scripted-unscripted sequence for instructions had a positive effect on group-efficacy. When face-to-face groups used scripted instructions they felt more satisfied with discussion process than when using unscripted instructions. In contrast, computer mediated groups felt equally satisfied when using both forms of instruction.

Introduction

Education is a social process, and social interaction among students is regarded as a critical variable in learning and cognitive development (Harasim, 1990) at all education levels. Computer-mediated communication (CMC) technologies offer potential for including many forms of social interaction in online learning contexts. There has been a major challenge for distance educators to develop instructional strategies which can effectively cultivate a consistent level of interaction and sustain the interaction in online learning environments (Muirhead, 2004). Research is needed to help examine what instructional strategies can be used to support high quality interactions in online learning so as to produce improved learning outcomes in higher education. Kreijns (2004) has suggested using traditional classroom-based cooperative techniques as a starting point to reexamine if classroom-based cooperative techniques are equally effective in computer-mediated contexts. Scripted cooperation uses a script to offer a procedural structure, where every step of the cooperation is prescribed so as to promote the occurrence of the desired cognitive processes and reduce the occurrence of negative social processes (O' Donnell & Dansereau, 1992). In face to face contexts, laboratory studies have shown that students who use scripted cooperation consistently outperform those who work alone and they also report positive attitudes toward their partners and collaboration (O' Donnell, 1992). Cooperation scripts developed and tested in face-to-face learning settings have potential to facilitate cooperative learning in computer mediated learning environments. Early results of research show that cooperation scripts may be effective when used in computer-mediated settings (Weinberger, Etrl, Fischer & Mandl, 2005). The purpose of the experimental study was to investigate the influence of cooperation scripts on achievement, group-efficacy, and satisfaction with group discussion process across technology-based or face-to-face contexts.

Methodology

The sample of the study was undergraduate students enrolled in a large lecture introductory course. Participants were randomly assigned into small groups of three members. Before the study, a demonstration of Blackboard and a small activity of using those online tools were provided to all the students to get familiar with the relevant online tools. In the study, two different case studies each lasting one week were utilized as an outside class assignment. Each case study was designed with a cooperation script condition and a non-scripted cooperation condition. Students who received the first case with a cooperation script received the second case without a script and vice versa. The scripted instruction adopted from Weinberger (2003) was designed to have group members play two roles, an analyst for one question of a case and a constructive critic for the other two questions. All groups in the technology context of the course were instructed to use a discussion board and an email tool embedded in Blackboard to perform their small group activities whereas their counterparts in face-to-face groups performed without technology. The collected quantitative data included student examination scores and survey data. A four item group efficacy scale adopted from Salanova, Llorens, Cifre, and Schaufeli (2003) and a five item process satisfaction subscale from Green and Taber (1980) were administered after each assignment through a web based survey. All items on the questionnaires are rated on 7 point Likert scales (1 = strongly disagree to 7 = strongly agree). 200 students from the class volunteered to participate in the study by signing the consent form. The response rate for the first and second motivational survey was 94.5 % (188 of 200), and 88.3 % (167 of 188) respectively. After examining accuracy of data entry, missing data, univariate and multivariate outliers and manipulation checks for fidelity to the between-subjects treatments, a total of 88 participants were included in the final analysis.

Findings

The reliability coefficients of group efficacy and process satisfaction on the full dataset were 0.84 and 0.76 respectively. Paired T-tests comparisons were conducted to examine whether there was statistically significance the change in measurements for each outcome variable at the two time points. The results showed significant increases on group efficacy and satisfaction, and a decrease on test scores indicating a confounding time effect on each outcome variable. In order to remove the confounding time effect, adjustments were made for three outcome variables. Two approaches for adjustments were adopted. The computation of z scores for each task was carried out on examination scores while the deviation scores for each task were used for group efficacy and satisfaction. Prior to the analyses, a sequence variable defined as students that received the unscripted treatment first versus the students that received the scripted treatment first was added into the analysis. Three separate repeated measures analysis of variance (ANOVA) with technology implementation and sequence as between-subjects variables and cooperation script as the within-subjects variable were performed to examine differences among the four treatments on the z scores of examination scores on each task and the deviation scores of motivational and affective measures from the mean value on each task. Examining the within-subject effects on examination scores, group efficacy and process satisfaction reveals that the main effects for cooperation scripts on group efficacy were significant, $F(1, 84) = 4.934$, $p < 0.05$ ($M = 5.90$ in the unscripted treatment vs. $M = 6.04$ in the scripted treatment). The result of between-subjects effects for the technology implementation variable achieved statistical significance for process satisfaction, $F(1, 84) = 5.117$, $p < 0.05$ (M= 5.873 in f2f groups vs. M= 5.494 in online groups). The interaction effect between Cooperation script and Technology on process satisfaction is significant, $F(1, 84) = 4.506$, $p < 0.05$ ($M = 5.729$ in the unscripted treatment and $M = 6.000$ in the scripted treatment for face-to-face groups vs. $M = 5.615$ in the unscripted treatment and M = 5.373 in the scripted treatment for computer-mediated groups). Simple effects analyses revealed that the effect of cooperation script was significant in the face-to-face groups, $F(1, 33) = 5.713$, $p < 0.05$ and was not significant in the computer-mediated groups, $F(1, 33) = 1.724$, $p > 0.05$. Additionally, the main effect of sequence on group efficacy is significant, $F(1, 84) = 6.85$, $p < 0.05$ ($M = 5.77$, in the unscripted - scripted sequence vs. $M = 6.13$ in the scripted – unscripted sequence).

Discussions

The purpose of the study was to examine the effect of cooperation script and technology implementation on achievement, group efficacy and process satisfaction of college students who participated in small group cooperative learning. In the study, students in both face-to-face and computer mediated groups scored similarly on achievement and motivation measures. Of note is that the face to face grouping shows no advantage over the computer mediated grouping on academic performance, and this finding is consistent with previous literature (e.g. Francescato, Porcelli, Mebance, Cuddetta, Klobas, & Renzi, 2006). Scripted cooperation has shown a positive effect on student's cognitive outcomes in face-to-face learning context (O' Donnell, Dansereau, Hall, & Rocklin, 1987; O'Ddonnell, 1996). However, prior research by Weinberger et al (2005) and Weinberger, Reiserer, Ertl, Fischer, & Mandl (2005) has shown that the individual acquisition of knowledge in a computer-mediated unscripted condition was better than in a scripted condition. The current study shows that there is no advantage for scripted cooperation over unscripted cooperation on examination scores in face-to-face groups and computer mediated groups. While some research suggests that cooperation scripts might de-motivate learners due to the strict regulation of social interaction (Rummel & Spada, 2005), the results of this study indicate that students receiving scripted instruction perceived higher group-efficacy than those receiving unscripted instructions. The sequence of receiving scripted and unscripted instruction had its impact on group efficacy of students. Students receiving instructions with the unscripted-scripted sequence perceived less group efficacy than those with the scripted-unscripted sequence. Additionally, face-to-face groups employing the scripted instruction felt more satisfied with their discussion process than those with the unscripted instruction. In contrast, computer mediated groups employing the unscripted instruction were as satisfied with the discuss process as when employing the scripted instruction. In summary the key findings are that cooperative learning was shown to be as effective in a computer mediated context as in a face to face context for both achievement outcomes and motivational attributions, and that the use of scripts support student efficacy for learning both in face-to-face groups and computer-mediated groups but has an advantage for process satisfaction only in face-to-face groups. These findings provide support for educators concerned with using cooperative learning techniques in online and distance learning environments and provide new evidence for advancing theory about how scripts influence outcomes and motivation in cooperative learning.

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Learning from Digital Video: An Exploration of How Interactions Affect Outcomes

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Abstract: The sinking costs of producing digital video and its growing presence on the Internet suggest that it has potential for use in web-based learning technologies. However, there have been few investigations into how the kind of interaction one has with video impacts subsequent learning. In this in-progress study participants are asked to watch video of an expert taking apart a toaster and describing how it works. The recorded event is the same for all participants, but the event is presented in one of three different modalities: (1) digital video shot from a free-standing camera (2) digital video shot from a free-standing camera that has been annotated in a video mark-up application called DIVER and (3) digital video shot from a head-mounted camera. A number of different assessment tasks are used to characterize the quantity and type of learning that is supported by a particular mode of video interaction.

Video-Based Learning and Interactivity

Decreasing costs and increasing accessibility of digital video technologies has made it remarkably easy to capture and share a significant event. There is tremendous potential for people to learn from watching a video that someone else has recorded because they may contain vivid descriptions of expert knowledge or a demonstration of expert practice (e.g., a video of an art historian deconstructing the scenes in Picasso's *Guernica*). In certain visually-based domains a video is likely to have more instructional value than a text-based description of the same event. Video-sharing platforms such as *YouTube* have led to an explosion in the number of digital videos available for viewing online by a widespread and continually increasing audience. While not all of the videos uploaded on the Internet have educational value, there is clearly the potential for online video to serve as a powerful medium for learning and collaboration. For this potential to realized, however, there is still much more that needs to be understood about how the construction and presentation of video affects the way we learn one another.

Previous research on learning from video has been limited to linear, non-interactive video, such as television (for a review see Seels, Fullerton, Berry & Horn, 1996). Digital video creates the possibility for new kinds of interactions with video, both in terms how the video is recorded and how people are able to manipulate and share existing footage. Lightweight and extremely portable video cameras can be purchased cheaply such that multiple cameras can be used to record the same event from different perspectives. Likewise, there are online tools becoming available that allow users create text annotations of video clips as well as perform basic video editing tasks. One such tool that was developed in our lab is called DIVER (Digital Interactive Video Exploration and Reflection) (Pea et al., 2004) and it was designed specifically to support online collaboration for the analysis of video data—it's a process we refer to as computer-supported collaborative video analysis, or CSCVA (Pea, Lindgren, & Rosen, 2006). While the different kinds of interactions one is able to have with digital video is rapidly increasing, there is a lack of research that speaks to how these interactions facilitate learning or create successful collaborations. In this paper we argue that this research is necessary because different ways of looking at the same event can change how one learns from that event, and thus it may be important to the design of video-based learning technologies. To this end, we describe the design of study in progress that looks at how the camera point of view affects the outcomes of a learning assessment in a novel domain.

Point of View

One way to change a learning interaction is to switch the perspective from which a learner is experiencing the event of interest. Most educational videos, for example, are recorded from the third-person perspective—a camera in a fixed position records the scene from the perspective of an "unseen other." By contrast, current technology makes it possible to capture a scene from the first-person perspective—the camera takes on the perspective of someone actually experiencing the activity of interest. This is generally accomplished via a wearable camera that is attached to a person in such a way that the camera's field of view approximates that of the person wearing it.

There is reason to believe that viewing a digital video taken from the first person perspective would have a learning benefit over a video taken from the third-person perspective. Goodwin (1994) describes a characteristic of experts in a given domain called *professional vision,* which is a way to describe how an expert literally sees the domain differently then a novice looking at the same domain. For example, Goodwin describes how a seasoned archeologist can perceive patterns in the dirt at the site of a dig that an archeological student does not perceive. Following this logic, it's possible that if a novice had the opportunity to see the scene in the same way that an expert sees it (e.g. attending to the aspects of the scene that the expert has come to recognize as important) then it may be easier for the novice to learn in the domain and hasten the path to becoming an expert themselves. Thus, a video captured in the first-person may have a learning benefit because it contains elements of perceptual expertise that are not present in a video captured from a fixed third-person perspective.

Another reason that the first person perspective may benefit learning is that seeing a scene through the eyes of a knowledgeable actor may lead the viewer to embody the expertise demonstrated in the video. In other words, seeing an activity as an expert sees it may elicit feelings of confidence and motivation as if they were the expert themselves. A first-person perspective may also give viewers a feeling of social presence, or the sense that they are actually interacting in the environment as opposed to being a passive observer. This too may have motivational effects that lead to greater subsequent learning.

Study Design

This study was designed to contrast learning from digital video of the same event recorded in the first or third person perspective. The first-person perspective was accomplished using a camera attached to a headband worn by the subject matter expert in the video. The third-person perspective was accomplished by recording the same simultaneous event using a camera on a tripod focused over the shoulder of the subject matter expert. The specific content that we chose for this study is a video recording of an expert disassembling a toaster and describing how it works. Toasters are surprisingly complex instruments that employ several key concepts from physics and electricity. Very few people understand the functionality of a toaster, and describing how one works is a highly visual task that was well suited for a video-learning study.

Head Cam

In the last few years some researchers in the social sciences have begun equipping their participants with head-mounted cameras as a way to collect data about aspects of human behavior such as communication and collaboration (for an example, see Fussell, Setlock, & Kraut, 2003). We feel that viewing video recorded by a head cam is a unique opportunity to take on the perspective of another individual, and we were interested in how easily the adoption of an expert's perspective would translate to learning. For this study we fitted the toaster expert with a Sony Super HAD high-resolution camera that recorded to a mini-DV deck. This video was transferred to a computer and processed into a QuickTime movie file.

Study Procedures

When completed, a total of 30 participants will be run in this study with 15 participants each in the first and third-perspective conditions. Each session begins with the participant completing a short survey that is used to assess the participant's prior knowledge of toasters and other related domains (e.g., physical mechanics). Next the participant is told that they will have the opportunity to view some video and that their task is to use the materials to learn as much as possible about how a toaster works in 15 minutes. Participants will view either the video recorded from the tripod-mounted camera or the head cam video (see Figures 1a and 1b for a screen shot of each condition):

1. Video from a tripod-mounted camera + passage (Figure 1a): In this condition, participants are presented with the toaster video in the QuickTime digital video player on a laptop computer. The participant is also given a piece of paper with a passage that describes the functionality of a toaster. Some of the information in the passage is redundant information presented in the video, and some of the information is novel. Prior to starting, the participant is given brief instructions on how to use the video player.
2. Video from a head-mounted camera + passage (Figure 1b): This condition is identical to the first condition except that the video used is recorded from a head camera. The head cam video was recorded at the same time as the tripod-mounted camera so that the audio and the events captured in both conditions are the same.

a b

Figure 1. Toaster video from a tripod-mounted camera (a) and from a head-mounted camera (b).

Learning Assessments and Data Collection

After the participants in each of the conditions have reviewed their materials, a series of assessments are administered. Each of these assessments target a different form of knowledge or understanding in order to determine if different types of video interactions support different kinds of learning. Participants are asked to complete four tasks: (1) Answer a series of paper-based conceptual and vocabulary questions (e.g., "Why are the filaments in a toaster wound more tightly at the bottom than at the top?") (2) Describe how a toaster works to someone who doesn't know (3) Describe how they would troubleshoot a series of hypothetical toaster malfunctions (e.g., "The toaster is plugged in and the tray stays down, but my bread isn't heating up.") and (4) Draw a functional diagram of a toaster.

In addition to the paper-based learning assessments, we are also looking at the participants' physiological arousal while watching the two different videos. Prior to watching the video the experimenter hooked the participants up to a device that records the participants skin conductance and heart rate, which are commonly used as measures of arousal.

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Fostering collaborative problem solving for pupils with cognitive disabilities

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Abstract: Verbal communication, particularly the ability to give directions and understand them, is a key not only for learning but also for every day life. Since one main objective of schools for pupils with cognitive disability is to prepare them to manage their every day life on their own as much as possible, we expect that teaching pupils to learn and work collaboratively by sharing tasks and give directions to each other will support this process and provide them in becoming more independent. In this paper we will present a short study and approaches we have elaborated to increase quality and quantity of users' contributions and foster verbal communication between pupils in collaborative problem solving tasks.

Introduction

"Technology as a teaching tool immediately, profoundly, and positively impacted the education of individuals with mental retardation … The introduction of the computer as a teaching tool … can be viewed as the greatest agent of change …for individuals with mental retardation." (Jeffs, et al., 2003). This euphoric description is representative for the appraisal of the use of computers in schools for students with cognitive disabilities. A Computer can be used as an effective learning tool to support the acquisition of basic learning skills (Zentel, Opfermann, & Krewinkel, 2006). In addition, the work with this medium supports the increase of self-determination, of independence, and integration skills (Wehmeyer, 1998) and allows for "positive changes in inter- and intrapersonal relationships, sensory abilities and cognitive capabilities, communication skills, motor performance, self-maintenance, leisure, and productively." (Parette, 1997).

Whereas most of these positive effects are measured in the context of individual learning we would like to enhance the focus on the potential of the computer to support processes of collaborative learning (CL) among pupils with cognitive disabilities. As part of a project for the development of a software toolkit for pupils with cognitive disabilities funded by the Federal Ministry of Education of Baden-Württemberg (Germany) we are conducting an explorative study to receive a first impression whether CSCL can be beneficial for this target group or not.

The software development within the project is done using the FreeStyler framework (Hoppe & Gassner, 2002) developed by COLLIDE research group at University Duisburg-Essen, Germany. Its capability has been proven in several projects with primary and secondary schools and in academic education (Lingnau et al., 2003b).

Collaborative learning & cognitive disabilities

According to Slavin (1999), CL is one of the greatest success stories in the history of educational innovation. The use of this instructional method has been proved in numerous studies in the traditional classroom as well as in computer based settings. However, only a few efforts have been made regarding the research of CL and CSCL on pupils with cognitive disabilities. Three research reviews (Tateyama-Sniezek, 1990; Stevens & Slavin, 1991; McMaster & Fuchs, 2002) stated mixed results in studies in which CL was used to improve the academic achievement of students with cognitive disabilities. Stevens and Slavin (1991) suggested that the reasons for the equivocal results can be seen in the variety of CL and the fact that some emphasise the academic achievement of pupils with cognitive disabilities to a much greater extent than others. The main result of their review is that the achievements of students with disabilities will be greater if CL includes individual accountability and group awards.

Beyond these methodological difficulties Cosden, Goldman, and Hine (1990) described fundamental problems of pupils with cognitive disabilities engaged in small group activities: pupils with cognitive disabilities are less effective communicators than non-handicapped, they are less effective in expressing their own point of view as well as in responding to the needs of the listener. They have problems taking over leadership during group activities and demonstrate considerable inconsistency in level and appropriateness of their communicative skills. Cosden et al. state that "it seemed plausible to expect that students with learning disabilities would have difficulty making effective use of collaborative groups to the extent that their communicative problems inhibit effective group participation." (ibid., p. 222). Although these global attributions may not apply to all individuals, they are describing potential problems that might occur in CL settings for this target group.

Preliminary studies

In our first study, we tried to explore which kind of setting might be reasonable for the target group of pupils with cognitive disabilities. In Lingnau, Hoppe & Mannhaupt (2003a) a study is reported where two primary school learners with heterogeneous ability solved a problem collaboratively in a jigsaw design. The study showed that even two low attaining children produced better results when working together instead on their own. Beyond they where stimulated to collaborate not only in the shared workspace but also by verbal communication discussing their actions and contributions to the shared workspace.

Coming from these results we analysed three different settings using the shared workspace of FreeStyler in a face-to-face situation with 2 tablet pc's. The test persons were 8 adolescents aged 17 to 19 from a school for students with cognitive disability with different aetiology. The speech of all of them was understandable. Participation was voluntary. In the first setting pupils should solve a puzzle collaboratively using the standard puzzle we implemented. The number of pieces can be varied and if a puzzle piece is dragged to the correct position on the puzzle frame, it will snap into the frame and be fixed. In the second setting, we had a maze as a background image. The pupils where asked to plot the way out of the maze in the shared workspace by using different colours. In the last setting the pupils where asked to paint a picture in the shared workspace by choosing from a list of objects e.g. a car, a house or a tree. We evaluated different pairs of pupils working on one or more of the three settings in an informal way but using video recording and FreeStyler log files which can be replayed, parsed and analysed. As a result, we concluded that the task description should provide a scaffold to guide the pupils through the task and that the pupils must be encouraged to communicate and coordinate themselves.

Collaborative puzzle solving

For the second study, we defined a setting following the idea of a jigsaw design i.e. one pupil cannot solve the task without the other. Two pupils from the same school mentioned above had to solve a puzzle collaboratively using 2 tablet pc's in a face-to-face situation. To measure their skills in this particular task in a short assessment the two candidates had to solve four puzzles with increasing difficulty (from 12 to 24 pieces) individually. Their performance was quite different. One of them was three times faster than the other. Furthermore he used goal-oriented strategies. The slower one had problems to find a starting point. After finding some correct pieces he continued solving the task by trial and error.

In the study each pupil got half of the puzzle pieces in a private workspace while the target image was presented as a preview icon in the shared workspace. The task was to bring together the puzzle pieces while taking turns in adding pieces to the shared workspace or re-arrange them. We identified four main types of action:

(1) Adding a piece from private to shared workspace to a random/wrong position
(2) Adding a piece from private to shared workspace to the correct position
(3) Moving a piece within the shared workspace to a random/wrong position
(4) Moving a piece within the shared workspace to the correct position

Table 1: Evaluation result from the FreeStyler log file

Task	overall actions		actions leading to correct solution	
	pupil 1	pupil 2	pupil 1	pupil 2
12 pieces (6 each)	4 (28.6%)	10 (71.4%)	2 (20.0%)	8 (80.0%)
12 pieces (6 each)	7 (35.0%)	13 (65.0%)	4 (33.3%)	8 (66.6%)
16 pieces (8 each)	13 (32.5%)	27 (67.5%)	0 (0.0%)	14 (100.0%)
20 pieces (10 each)	16 (26.2%)	45 (73.8%)	3 (15.0%)	17 (85.0%)

The analysis of the log files (see Table 1) provides evidence that the type of actions of the two pupils differed significantly. The results show a ration of approx. 1:2 in the contributed actions of the two subjects, i.e. the higher attaining pupil did two thirds of the overall actions. Although there were differences in their performance during the initial assessment both pupils were able to solve the puzzles. In the collaborative setting, we observed that not only the higher attaining pupil took the leadership but that also the lower attaining pupil backed off from being an active and mindful contributor. Since he had to contribute at least one action in the shared workspace when it was his turn he mostly just added one of his puzzle pieces to a random position or moved a piece to a random but wrong position in the puzzle. The higher attaining pupil waited his turn and undid this action by moving the piece to either the correct position or just back.

Conclusion and Outlook

Since we observed indications for a more collaborative behaviour, we will modify the puzzle setting to guide the pupils to problem solving through acting in shared workspaces and verbal communication. Margaritis, Avouris & Kahrimanis (2006) and Vassileva (2004) showed that enabling learners to reflect on their participation in collaboration through awareness mechanisms can change and increase the quantity and/or quality of contributions to CL. Margaritis et al. found out that providing the user with a *state of collaboration* index "… is easy to interpret, not requiring high cognitive load and focusing ability of the partners concerned …". We assume that such awareness information will stimulate and increase collaboration between pupils with cognitive disabilities too.

Following the approach of scripting tasks for CL (Fischer, et. al., 2007), we will modify the setting using different layers in the workspace. This mechanism is implemented in FreeStyler, i.e. the pupils are using a shared workspace but each pupil is using his own transparent layer where objects can be manipulated only by him but changes are visible to the other. In such a setting the puzzle task can be accomplished avoiding that one pupil can solve the task without the others help when all pieces are in the workspace. Combining these two variations of our setting we want to study whether we can stimulate collaboration and accomplish and foster verbal communication between the learners. Similar to examples of collaborative problem solving with early learners described by Lingnau, et. al. (2003a) we expect that even learners with cognitive disabilities will benefit from collaboration.

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