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Table of Contents

Introduction

Papers

The Effect of Window State on User Behavior in an On-Line Computer Mediated Conference

Terence C. Ahern

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Abstract

The goal of this study was to investigate the effect the window state and management on the ability of users to maintain coherent interaction within an on-line mediated conference. Industry design practice suggests that users should be able have direct control of the windowing display system. In order to conform to industry practice the IdeaWeb was redesigned from a single window display system to a modeless tiled window display system. It was assumed that a modeless windowing system would be preferable because the underlying graphic display system was dynamic.

The results indicate that the students generally opted for a single window display system which is consistent with much of the previous research. Sequence data from the event logs demonstrate that students chose to treat the modeless window as static or modal. It appears that the students were concentrating on the cognitive task of managing the on-going computer mediated discussion.

This study has important consequences for screen and window design not only for developing on-line conference systems, but within multimedia systems that have dense cognitive material. If the cognitive requirements of the main window are high, then a titled windowing system that requires little user intervention appears to be the design choice. However, if the requirement to recall information from window to window is low then a single window system display system is more appropriate. This would reduce not only the cognitive but the design and programming overhead as well.

Keywords — windows, computer -mediated communication, small group discussion.

1. Introduction

Collaborative learning as an instructional method has a long history. It can be found in the Academy of Plato to the one room school house of the 19th century. The positive effects of the many different forms of collaborative learning have been well documented. [1].

Social learning environments create situations in which schoolwork is perceived not as a "task" or "chore" but as an opportunity to interact on issues of personal importance. The advantage of authentic interaction provides not only individual cognitive development but also creates an important social environment with far reaching consequences. One of the many benefits of collaborative learning is that it requires students to challenge, reject or integrate the new information [2] which leads to deeper understanding. In a social environment students engage their peers with talk that informs, explains, persuades or even entertains. This process is provides what Stasser and Davis [3] terms knowledge building and is accomplished when one tests an understanding against the "common authority" and requires access to multiple perspectives other than one's own.

Even though collaborative learning is viewed as a legitimate method for classroom instruction, experts suggest that less than 10 percent of the nations schools regularly use cooperative learning techniques [4]. Implementing a change from the traditional classroom to one that values discourse, therefore, is not a simple matter. However, networking technology may provide a solution to this dilemma. In fact "Technology is a great Trojan Horse... It is a great way to get cooperative learning in the door" [4, p. 27]. By providing the opportunity for authentic peer interaction, each student will development an awareness of authorship and the need for rhetorical competence. However, most computer systems were initially not developed for the more dynamic simultaneous multi-channel interaction of group interaction. Typically, "E-mail is a great tool for person-to-person messaging but it fall flat when you're coordinating a discussion... Traditional E-mail packages just weren't designed with work groups in mind: [5]. R. L. Bangert-Drowns [6] suggests that "different communication interfaces might be suited to different instructional tasks. In situations where students are not just discussing, but collaborating on goal-focused work. . .different interfaces might be needed". Levin, Kim and Riel concur and speculate that "once we have a more detailed understanding of the nature of the interaction, we will be in a good position to address the issue of which medium is effective and for what purpose" [7,p.185]. Consequently, group interaction is hampered by the design of the user interface.

One area in which the typical social computing application breaks down is in its inability to manage the development of coherent discourse over time. McGrath [8] observed that when members can choose when to participate an unpredictable lag in feedback is created in contrast to typical face-to-face. In real time interaction an individual has the ability to index multiple speakers by tracking who-said-what-to whom-when. The ability to keep track of an ongoing conversation is accomplished through the use of turn-taking rules where one participant takes control of the floor and continues until they relinquish it to another which results in an orderly "distribution of talk among the various members" [9, p 296]. This indexing mechanism allows an individual to cogently and appropriately respond to a variety of different speakers at different times [9 p 296].

In a typical on-line system, however, individual responses are managed linearly making the thread of a discourse sequence difficult to follow. This break down in the ability of members to engage in a coherent interaction leads to “individual reasoning, not collective reasoning” [10, p.149] However, by merging the pragmatic needs of interaction with a conventionalized graphical representation participants in a collaborative learning system are be able to locally manage turns. This results in sustainable, coherent interaction.

The IdeaWeb© addressed this need by merging the pragmatic principles of conversation with a visually oriented interface. [11,12]. A salient feature of the IdeaWeb is the user display system which requires each group member to map their interactions visually thereby enabling group members to quickly determine not only to whom a message was intended but also the position of that message in an on-going sequence of messages [12] .

The intial version of the IdeaWeb used a single window display system. However, it was assumed that the visual display system played an important role in helping the user to contextualize previous messages. With the current design, the graphic display is obscured while the user is reading previous messages. Consequently, in order to improve performance within the system and to conform with current interface practice the IdeaWeb was redesigned in order to implement a multiple window system providing the users with more control [13].

Previous window design research indicates that user performance is effected not only by type of the window display system but also by the cognitive requirements of the task. For example, in a study that explored the ability of users to find information in a single text window in contrast to multiple overlapping windows, it was found that novice users performed much better on the task using the single window display. However, as the users became more proficient in the task and more efficient in using the interface, the readers “benefited more from multi-windowing displays because these helped them locate the information they have just read" [14, p. 613]. Further, Aspillaga [15] investigated the effect of window location in conjunction with the overlapping of graphic information in a language tutorial. She found that a consistent window position had a significant effect on performance than the overlapping of a graphic illustration. Benshoof and Hooper [16] in a study using a CAI tutorial found that high ability students performed significantly better in the single window treatment than all other students.. They suggest that the single window display may have helped the students to process information more deeply. They caution however, that these results may be due to the superior cognitive skills of the high ability students who were able to overcome the higher processing memory requirements of the single window display. In a more recent study this caution seems to be well founded as Benshoof, Graves and Hooper [17] report that all students performed significantly better in a tiled multi-window display system because it acted as supplementary memory aid in support of the main window.

Modern windowing systems allow for not only the positioning of windows such as overlapping and tiling but also different window states. The primary state for most applications has the foremost window active and is considered the top window. If other windows are simultaneously open, they are inactive and are located behind the main window. To activate a background window, a user would choose a window by clicking the mouse somewhere within its boundary. This action changes the state of the current main window to inactive and moves it to the background while bringing the selected window to the top. Normally, a user could perform this action at any time. However if the top window is in a modal state, the user must first complete a task in order to either dismiss, activate or manipulate another window. On the other hand if the top window is in a floating, modeless state, moving between windows does not require activation or result in a state change because all windows are active.

Schneiderman [18] suggests that a "general problem for computer users is the need to consult multiple sources rapidly, while minimally disrupting their concentration on their task." [18, p. 337]. The IdeaWeb was designed to enhance coherence by inhibiting the breakdown of interaction by supporting context building through the graphic display of the links between messages in an going sequence of interaction. It was assumed that maintaining coherence in the IdeaWeb would be enhanced by allowing the user not only to read continuous sequences of comments but also to reposition or resize the window in order to be able to view the position of the current node in a sequence of nodes. Therefore to conform with current interface design principles a modeless window system would permit the user to reposition, resize the window thus would allowing the user to view the underlying graphic with minimal interference from the system.

In contrast, Shneiderman [18] also argues that dense, crowded and complicated displays are difficult for novices to use, the typical student in most instructional situations. If Schneiderman is correct then the high cognitive requirements of managing asynchronous interaction in a computer mediated system would suggest a single modal window system would be preferable. The system would require each user to view a sequence of interaction without the distracting interference of the graphic display or the need to mangage the window such as resizing or repositioning. Consequently this study investigated the effect of the window state on user's behavior in an on-line mediated coherence.

2. Method

2.1. Subjects

In order to investigate the effect of window modality 32 undergraduates in a self-paced introductory computer literacy course at a major southwestern university volunteered to participate in this study. The students had little previous computer experience. Students who met the minimum requirements of participation received bonus academic credit for the course.

2.2. Materials

As indicated before the salient feature of the IdeaWeb is the displaying of previous comments as a web of interactions. (Figure 1).

The IdeaWeb was modified so that there were two conditions. The first condition used a floating, modeless tiled window display system which could be repositioned, resized or closed at any time by the user. (Figure 2).

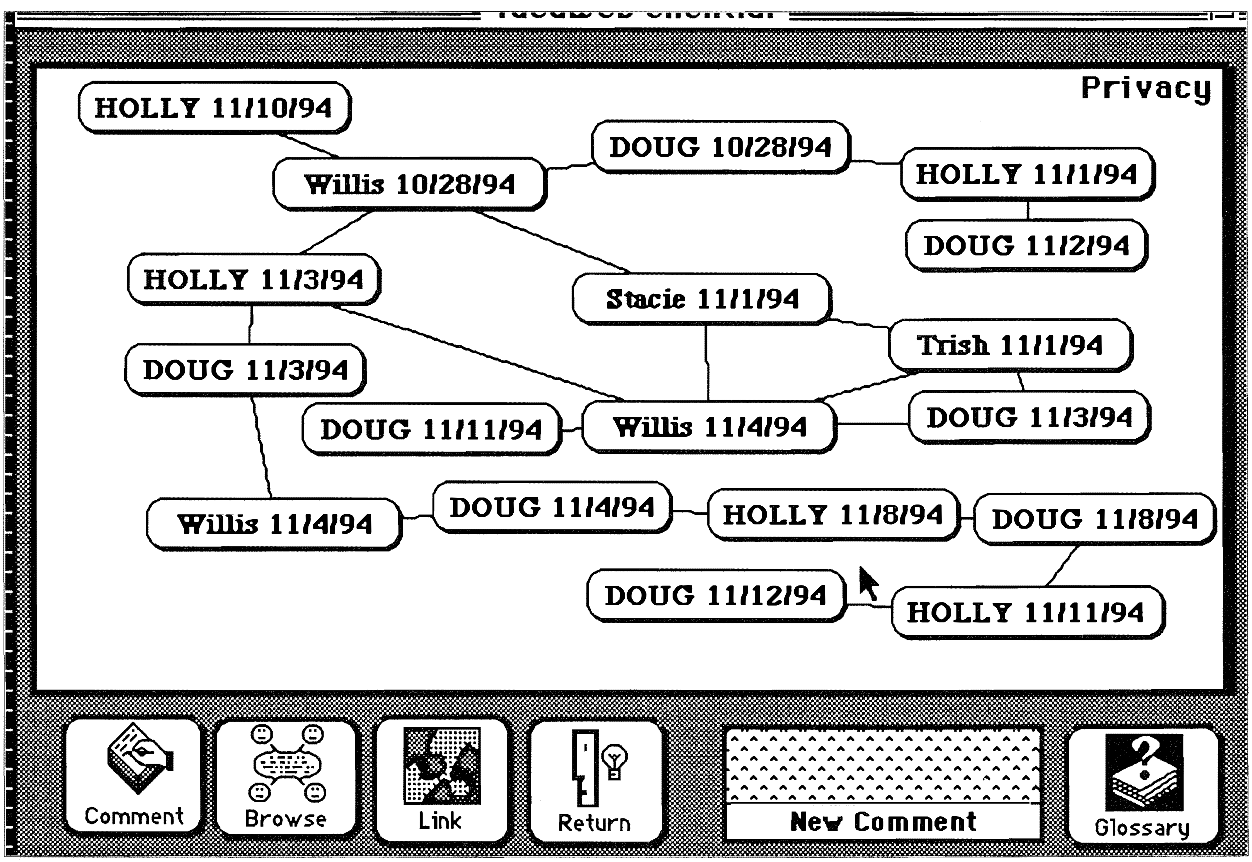

Figure 1. Web of interactions.

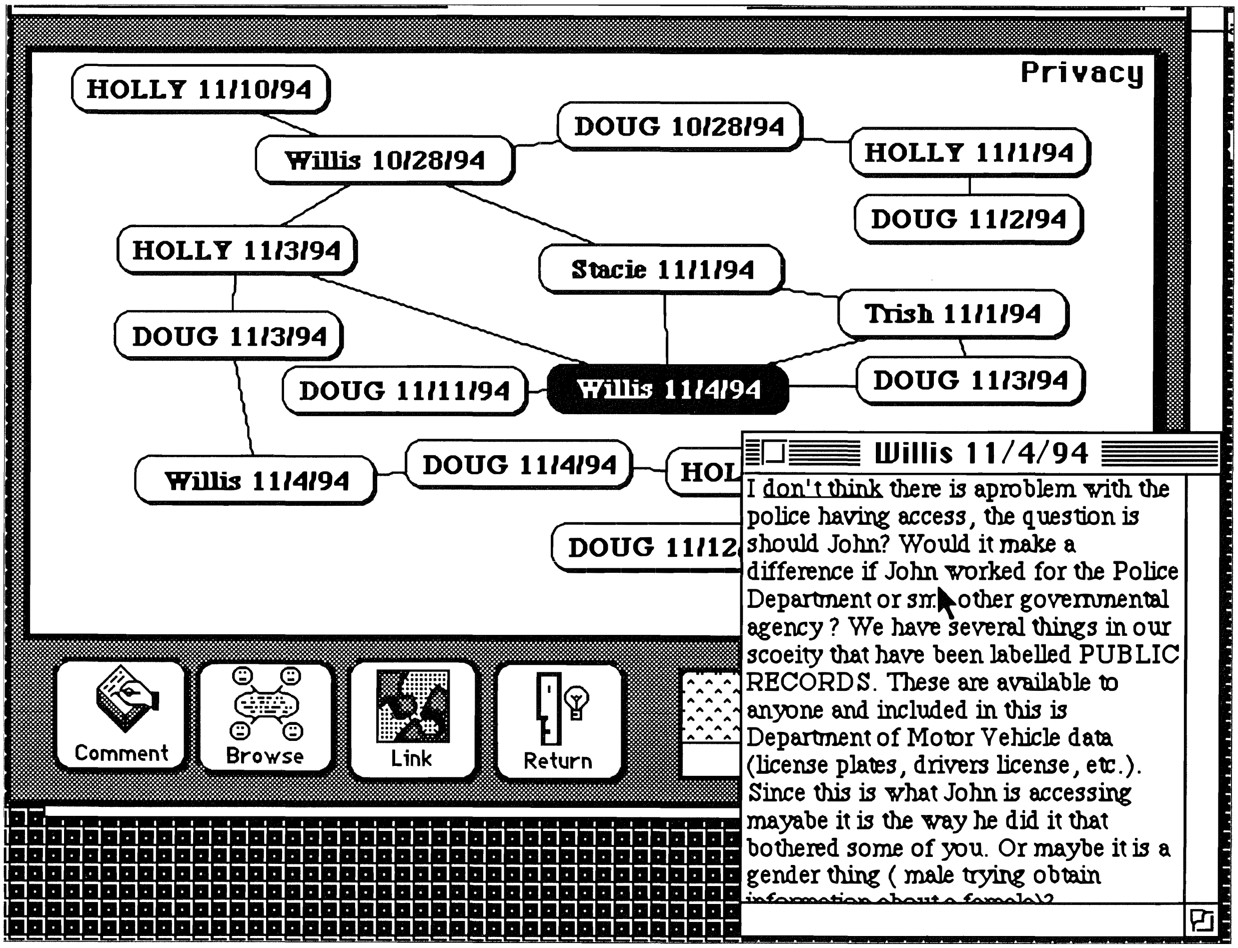

Figure 2. Modeless window moved and resized.

The second condition used a single window modal display system that not only obscured the graphic, but also required the user to review a sequence of messages prior to returning to the graphic display.

2.3. Procedure

Experimental conditions were based on the window display system. The students were randomly assigned to 8 discussion groups of approximately 5 members per group. They were to participate in a laissez-faire discussion concerning some topic. In addition, other topics provided an area for announcements of interest to members of the group and another for the users to voice concerns about the study, credit, and problems with the software etc. The students were required to use the system at least twice a week during study.

2.4. Data Collection

This study used a mixed design with an within-subject independent variable of window state [modal and modeless window] and a between subject independent variable of group. Each group was randomly assigned and trained in the use of a particular window condition. At the end of a two week period, each group was re-assigned and re-trained during an interim week on the use of the new window condition. The study continued for a second two weeks and maintained an event log for each member each time they logged on.

3. Analysis

The dependent variables of participation, time, number of messages, and length of messages were analyzed using a completely randomized block design with repeated measures. There was no main effect for groups. However, there was a main significant (WILKS' LAMBDA [3,22]= 62.5251775 P=0.000) effect within subjects by interface. However, subsequent univariate investigations were not significant for number of visits, length of messages, number of messages or number of words per message.

Table 1. Repeated Measures Table

Between Subjects					
Source	SS	DF	MS	F	P
Group	2393.61	7	341.9	1.3	0.288
Error	6263.29	4	260.9		
Within Subjects					
Interface	79528.7	3	26509.5	154	0
Interface * Group	7886.3	21	375.5	2.2	0.007
Error	12367	72	171.7		

Link data was modeled using directed graph theory. Initially, the individual messages by window state were arrayed into an adjacency matrix for each group's subtopic. Formally, an adjacency matrix A(D) = (a_{ij}) is defined as a square matrix in which a_{ij} represents each individual message as defined by the intersection of row i with column j [19,20,21]. If a message in row (v_i) is linked to a message in column v_j the resulting value of a_{ij} is scored 1, otherwise the value of a_{ij} is scored 0.

An adjacency table allows for the investigation of additional information. The outdgree or row sum indicates the number of directed links a particular node makes to any other node.

The outdegree data was found to be was significant (χ^2= (3,N=292)=9.167, π = 0.027) by window type. The modal window environment produced more multiple node links than the modaless windowing system.

Table 2. Link Frequency by State

	1	2	3	4	Total
Modeless	10	89	26	9	134
Modal	18	117	21	2	158
Total	28	206	47	11	292

Statistic	VALUE	DF	P
Chi-Square	9.17	3	.03

The adjacency matrix also allows for the construction of a distance matrix [19] which tabulates the length of interconnected nodes. By raising the adjacency matrix to a power indicates the length of the path between the nodes. If an integer appears in any of the cells, it indicates that the row node is a specific number of links away from the column node as determined by the power to which the matrix was raised. Therefore, if the adjacency matrix is squared (A x A) the data can be arrayed in a distance matrix for further analysis. The resulting analysis indicates that there was no statistical difference between the two window states in the length of discourse sequences (see table 3).

Finally, a tally matrix according to events was constructed out of the sequential data as recorded by the event log. A first order Markov process was found in the sequence data (see table 4) as indicated by the transition probability matrix.

This table shows the events and the probabity of an event following an event. For example a window opening followed by a node was 100%. Additionally it indicates that a node followed by a window occured almost 42% of the time. The window-node-window or

Table 3. Frequency of Sequence Length by Window State

	1	2	3	4	5	6	7	8+	Total
Modeless	170	141	107	58	30	15	11	12	544
Modal	167	150	123	86	40	18	7	6	597
Total	337	291	230	144	70	33	18	18	1141

Statistic	Value	DF	P
Chi-Square	9.010	7	0.25

Table 4. Event Probabilities

Event	Window	Node	Resize	Move	Comment
Window	0	1	0	0	0
Node	0.417	0.386	0.020	0.020	0.155
Resize	0.571	0	0.142	0	0.285
Move	0.078	0	0.026	0.842	0.052
Comment	0.446	0	0	0	0.553

Statistic	Value	DF	p
Chi-Square	377.7	16	.000

window-node-node-comment were typical sequences within the modeless environment. These sequences mimic the modal environment which was controlled by the system. Notice that it illustrates that the participants chose to manipulate the modeless window system a litle more than 2% of the time either to reposition or resize the window.

4. Discussion

The goal of this study was to investigate the effect the window state and management on the ability of users to maintain coherent interaction within an on-line mediated conference. Industry design practice suggests that users should be able have direct control of the windowing display system. In order to conform to industry practice the IdeaWeb was redesigned from a single window display system to a modeless tiled window display system. It was assumed that a modeless windowing system would be preferable because the underlying graphic display system was dynamic.

Previous research on user performance in using different types of window display systems indicate that the cognitive task is an important design factor. Benshoof et al. (in press) found that when the main window was cognitively important, the tiling of the window provided a useful device to help recall important information. Aspillaga (1991), discovered that an overlapping window did not diminsh performance when the data being displayed was more important than viewing an underlying graphic on the main window. However, when the overlapping window was inconsistently located created a higher cognitive load with a subsequent decrease in user performance.

The results indicate that the students generally opted for a single window display system which is consistent with much of the previous research. Sequence data from the event logs demonstrate that students chose to treat the modeless window as static or modal because they so infrequently moved or resized it even though they were permitted to do so. It appears that the students were concentrating on the cognitive task of managing the on-going computer mediated discussion. This explains why there were no significant differences between the two window systems in terms of amount or length of the messages or in the length of the interaction sequences. The underlying graphic display of the link nodes served as a orienting device which once viewed could be obscured without disrupting the comprehension of the ongoing discussion.

Nonetheless, by only partially obscuring the underlying graphic (see figure 2) may have interfered with the students' concentration. This may explain why there was a significant difference in linking data between the systems. Users in the single window modal system were significantly more likely to link a comment to multiple nodes . Because the modal system forced students to review comments linked to a node prior to returning to the discussion screen the students could read previous comments without the visual interference of the graphic display. Even though this did not result in any significant improvement in the length of the interaction chains, it appears that the students had a better grasp of individual comments.

This study has important consequences for screen and window design not only for developing on-line conference systems, but within multimedia systems that have dense cognitive material. If the cognitive requirements of the main window are high, then a titled windowing system that requires little user intervention appears to be the design choice. However, if the requirement to recall information from window to window is low then a single window system display system is more appropriate. This would reduce not only the cognitive but the design and programming overhead as well.

This study also suggests further research. It would be of important to investigate if the users' performance or behavior would be altered as their expertise within the system improved. Additionally, if a tiling system was adopted, what is the saturation limit on the number of windows open simultaneously. Finally, what is the effect of a moveable, modal window system on user behavior. If social learning systems are to become integrated within the school we need not only an understanding of mediated interaction but also the most appropriate interface design for the task.

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Understanding the Collaborative Learning Process in a Technology Rich Environment: The Case of Children's Disagreements

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Abstract

Recognition of the importance of the social role in learning combined with the advancement of educational applications of computer technology has sparked the development of innovative learning situations. The resulting increased complexity in the social context in which the learning is occurring requires a more in-depth understanding of the learning process. Collaborative learning is gaining in popularity but we still need to establish what is meant by it and gain insight into its process. This paper proposes an innovative analytical framework for viewing the collaborative process. It reports on a study with elementary school aged children working with LEGO/Logo and their evolving understanding of the scientific concept of mechanical advantage. It comes as little surprise that children learning collaboratively is not always as collaborative as one might have expected. In fact, in this study disagreements arose frequently. Some of the findings are reported and support the view that disagreements can be a legitimate form of collaboration.

Keywords — Collaborative learning, situated learning, disagreement, learning process, conceptual change, LEGO/Logo, mechanical advantage, science education, classroom-based research, elementary school.

1. Introduction

Two important theoretical changes with respect to learning are at the root of the increasing interest in learning environments that provide computer support for collaborative learning. The first is the view of learning that considers both the social context and the social processes as an integral part of the learning activity (Brown, Collins, & Duguid, 1989, Greeno & Moore, 1993, Lave & Wenger, 1991, Resnick, 1991, Rogoff & Lave, 1984). The second is the recognition of the importance of learners actively constructing their knowledge as suggested by the theoretical viewpoint of constructivism.

The creation of learning environments that renders learning more active and in a more social context is initiating new challenges for research on learning. The combination of active learning and technology is creating learning situations that were, until very recently, unavailable for furthering our study of the learning process. Learning taking place in more social contexts, such as collaborative learning, is gaining in popularity both in classroom practice and research. Yet, very little is actually known about the process itself.

In the area of science and mathematics education the importance of active learning and in more social contexts is well asserted in the literature (Gardner, Greeno, Reif, Schoenfeld, diSessa, & Stage, 1990, Putnam, Lampert, Peterson, 1990). This change is extremely important as it necessitates the need for improving the examination of the learning process in these domains. Greeno (1990) suggests that: "Most research in science education treats learning in science as something that an individual student does. . . . we researchers of science education need to learn how to study the social phenomena of learning and understanding scientific concepts" (p. 181).

The developmental theories of both Piaget and Vygotsky provide interesting insight into the role of social interaction on cognitive growth. Their views differ in that for Piaget, social interaction is seen from the perspective of its role in the development of logical reasoning. While, for Vygotsky, social interaction is at the core of the developmental process and children's learning. In his theory, individual cognitive development is a process related to transforming socially regulated and mediated knowledge. See Confrey, (1994, 1995) and Tudge and Rogoff (1989) for a more detailed analysis of these two theories.

Resnick (1991) underlines the importance of looking at the influence of social interaction (e.g. asking questions, arguing, the elaboration of one's ideas) on the constructive process. She points out that there is a need to "seek mechanisms by which people actively shape each other's knowledge and reasoning processes" (p. 2). Technology rich environments are providing new opportunities for learning to occur in much more social contexts. In the emerging CSCL community, Pea (1994) suggests that we need "to be deeply conscious about the birth of CSCL as a discipline and a new approach to thinking about learning and education" (p. 297).

Both the use of the terminology and the criteria for establishing a collaborative learning situation vary in the literature. Looking at the terminology, terms used to describe collaborative learning include "peer collaboration" (Tudge & Rogoff, 1984), "collaborative learning" (Forman & Cazden, 1985), "coordinated learning" (Koshmann, 1994), and "collective learning" (Pea, 1994). Pea provides an insightful reflection when he argues for his choice of terms: "not all learning feels or probably is collaborative; it is sometimes competitive or coercive in nature" (p. 286). It is interesting to note this evolution of terms and the breadth of meaning that the terms are capturing in order to more realistically reflect the interactions among active learners.

The criteria for establishing a collaborative learning situation are also evolving. Forman and Cazden (1985) distinguished collaborative learning from other forms of peer interaction based on the task being performed. For them, "collaboration requires a mutual task in which the partners work together to produce something that neither could have produced alone" (p. 329). Tudge and Rogoff (1989) distinguished studies on peer collaboration from other studies on peer interaction on the basis of their focus on the actual process as opposed to just outcomes. This reflects the changing view of research on learning and the type of environments used to study the learning process.

In contrast to traditional classroom group work that is often artificial and imposed, collaboration in technology rich environments offers the potential for genuine collaboration to occur. The collaboration is genuine because collaborating with others is an optimal and desired form of working. An example of genuine collaboration in everyday life are emergency situations. Something happens (an earthquake, a bus accident) and total strangers work together to provide help, establish priorities, plan for the next move, organize others etc. There is a shared goal and the optimal solution is attained by working with others. In this paper, collaborative learning is viewed as working with others towards a common goal. The focus is on the process and more specifically the process as it occurs during disagreement between the collaborators.

Research on collaborative learning that focuses on the process rather than outcome is both recent and limited. It includes in the sociolinguistic tradition, work by Forman and Cazden (1985) that looked at social interactional patterns (parallel, associative, cooperative) and problem-solving strategies (random combinations, isolation of variables, systematic combinatorial strategy) during group problem solving. Part of their results showed that the most cooperative interactions that used the most combinatorial strategies solved the most problems. However, the pretest-posttest comparison did not show such clear benefits. Tudge (1990) raised an interesting question with respect to peer-peer interaction. Although the research on collaboration with peers often indicated cognitive advancement (Doise & Mugny, 1984, Perret-Clermont, 1980), Tudge showed that in certain circumstances peer interaction could result in development as well as regression.

Roschelle (1992) did a micro-analysis of the collaborative process to look at the convergence of meaning while learning science. The collaborative process in his work was examined as a continuous series of interactions. He looked at the collaborative process using an innovative simultaneous approach in which several perspectives of the same act were used for analytical purposes. These were: a) conversational action, b) the conceptual change from a cognitive perspective, and c) the shared knowledge from a social perspective. Roshchelle was able to show that a conceptual change occurred and that the "students arrived at a common shared new conceptualization" (p. 264). He described the process as being incremental, interactive and social.

Disagreements, although not always welcomed, are to be expected as learning becomes more active and social. The research tradition on children's disagreements typically examines them from an interpersonal perspective and, given the low tolerance for conflict in elementary school, focuses mostly on very young children (Shantz, 1987). Very little is known about substantive disagreement that occurs in a naturalistic learning setting.

2. The Study

The study looked at children's collaboration in a design and construction environment (LEGO/Logo) in which children had the opportunity to create and produce robotic inventions (Papert, 1986). The LEGO/Logo activities were integrated into the science and computer curriculum in a regular classroom. They took place twice a week for a duration of 45 minutes. The particular task that the children were working on was to build something that had a mechanical advantage (Barfurth & vanGelder, 1993, 1994, vanGelder & Barfurth, 1993).

In addition to coming up with ideas, during this five week project, the children also had to coordinate different ideas during the different stages of the design process. This study focused specifically on the disagreements the children had during the designing and building stages for their invention. The topics of the disagreements deal with structural, mechanical and physics problems implicit in the construction process.

One group of four children were randomly chosen from those groups in which all four children had consented to participate. The project combined children from a grade four and five classroom; each working group was composed of two children from each grade level. As it turned out, the group selected had a grade four and five girl and a grade four and five boy. One group of four children (2 from grade 4 and 2 from grade 5).

The principal data collection tool was a video camera placed on a tripod next to the group of four children. The video recordings were then transcribed. A qualitative data analysis program was used to help in the management of the data.

2.1. The analytical framework

The analytical framework presented in this study was designed to look at the collaborative learning process from two perspectives the social and the cognitive. The theoretical foundation for this analytical framework grows out of the more recent research that looks to both Piagetian and Vygotskian theories to further the understanding of peer interaction. Forman made an interesting suggestion with respect to the different perspectives of peer interaction as seen in the theoretical frameworks of both Piaget and Vygotsky.

> *Forman (1987) noted theoretical differences in the cognitive and social processes underlying collaborative problem solving in Piaget's and Vygotsky's theories. In Piaget's theory the parallels between cognitive and social processes are explained by the fact that both derive from the same central intrapsychological process, whereas in Vygotsky's theory the correspondence is due to the derivation of individual higher cognitive processes from joint social processes. These differing interpretations are accompanied by differences in the mechanism: intersubjectivity and perspective-taking. Forman suggested that intersubjectivity (from the Vygotskian perspective) is a process that takes place across people, whereas perspective-taking and decentering (from the Piagetian perspective) are individual processes working on socially provided information.*
>
> (Tudge & Rogoff, 1989, p. 29)

The differences in the mechanisms (intersubjectivity and perspective-taking) referred to by Forman in the above citation form the basis for the proposed analytical framework. The notion of a **social move** and a **cognitive move** is introduced to operationalize these two different perspectives.

The **social move:** One way of viewing the social (in the sense of intersubjective) perspective of the collaborative process would be to examine the process, as it occurs, across the participants. In other words, given a group of participants, this perspective looks at the process from the group as a whole and the interactions that occurred as a sequence between them. The notion of sequence is introduced to preserve the order in which the interactions occur between the participants.

The coding schema used to denote a social move is based on the structural analysis of disagreements done by researchers working in a sociolinguistic tradition (Eisenberg & Garvey, 1981; Genishi & Di Paolo, 1982; Wilkinson & Martino, 1993). The structure for a disagreement recognizes four basic components: an antecedent, opposition, resolution move, outcome.

A **cognitive move** partially reflects the other mechanism that Forman suggests above, that of the individual processes working on socially provided information. There are two working assumptions underlying the development of the concept of a cognitive move. These are:

(1) During social interaction a parallel individual cognitive process is taking place.

(2) (a) Each and every social act reflects an individual's cognitive act.

(b) This cognitive act can be identified.

A cognitive move therefore reflects the cognitive act that a person does in light of the social interaction. Unlike the social move that takes the perspective of across-people and from the group as a whole, a cognitive move is from the perspective of the individual and what this individual does in light of the information provided during the social interaction. Similar to the social move, the notion of sequence is introduced to preserve the order in which the cognitive moves take place both between the participants as well as for a given participant. Keeping the cognitive move relative to the social move as well as to the event itself allows for a more extensive analysis to be undertaken.

This coding schema was developed to capture the different cognitive moves that the individual children used while disagreeing during their collaborative work. These moves reflect the different options that the children had with respect to the information put forth by others during the disagreement. What follows is a description of the principal cognitive moves:

Initiate a topic: Make an explicit statement with respect to a particular topic. Example:

Patricia: [sliding axle through] Well maybe it will jam. [Turning] See it still doesn't touch. So we can't use a small one, Jeff. I told you we had to use a medium.

Add a new aspect with respect to the initiated topic: Contribute new or additional (could have been previously seen but not necessarily in the immediate) information about the topic at hand. Example:

Patricia: Oh [testing and turning] it's these. This [first two axles] works. It's this one that jams it [pointing to third axle].

Integrate others' position with yours: Taking into consideration what someone else has put forward on a topic. This newly integrated information could be correct as it could be incorrect. Example:

Filene: Instead of putting this one [points to third axle small gear] try that [points to fourth axle medium gear]

Patricia: O.K. Let's try [pulling off third axle]. [Answering Kenny's and Jeff's question of what are we doing right now?] Cause Filene got the idea that since it's the small gear that is so hard to turn// [Patricia is cut off].

Modify your own position: Having heard what someone else has put forward or having experimented with the material, you modify your own position. This modification could be major or minor. It could also result in a correct or incorrect outcome with respect to knowledge on the topic.

Patricia: [Finishing to re-install the second axle.] There, now it turns [Turning it, the first two axles turn and the last three do not.] Oh, it's these [pointing to the last three axles] This works [the first two axles].

In this example, based on her observations with the material, Patricia put forward a new hypothesis that it was the last three axles that were a problem because the first two worked. She modified her content based on her experience.

Maintain the same position: No change in the position held with respect to the topic under disagreement. This includes the situation in which one is not taking into account what other's are saying or disagreeing with what has been put forward. It can have the form of repeating what one has just said or paraphrasing. The example below illustrates Jeff maintaining his position over a segment of a disagreement.

1. Jeff: It doesn't make a difference [maintains his position]

5. Jeff: It's hard to turn it. That's the reason. It's because it's hard to turn it. [paraphrasing]

12. Jeff: You need a small gear to turn the big gear. [same position more explanation]

Ask for an explanation or clarification: A child explicitly asks for an explanation or clarification during the disagreement.

3. Jeff: What difference will it make where it is?

Quit altogether or take an observatory role: A child discontinues their participation in the disagreement.

Jeff: Look, you'll do everything and I'll watch. O.K.?

Kenny: I'm going to sleep [puts his head down on his folded arms.]

Table 1. Example of a Coded Disagreement.

Utterance	Social move	Cognitive move
0. Patricia: and then 'cause. You know what we could do, we could put a big gear here like another big gear	Antecedent	Initiate a topic
1. Kenny: No, it will slow it down.	Initial opposition	Add a new aspect
2. Filene: We don't have any big gears	Resolution	Add a new aspect
3. Kenny: Plus we don't have it. Plus it will ooh	Opposition-asserts alternative position	Modify position
4. Patricia: we could put the small one attached here [points to first axle large gear] and here [looks like the second axle medium gear]	Resolution	Add a new aspect
5. Kenny: [Playing with black LEGO chain] But the big gear, if we put a big gear it will go much slower cause the big gear ahh is much slower. If we add a big gear here [points to third axle area] it won't go as fast Filene. Believe me.	Opposition-asserts alternative position	Add a new aspect
6. Filene: Oh because this one [nods her head] I get it.	Resolution	Integrate other's position
7. Kenny: No, because the big gears are slower. Some girls are just//	Opposition-asserts alternative position	Maintains same position
8. Patricia: [Is sliding a fourth axle onto the invention with the small gear on the inside] No [to K], but this one [points to small gear] attached to the big gear will go even faster.	Outcome	Add a new aspect

Following each utterance in the second column is a label that uses the general structure of a disagreement to look at the social move perspective. The disagreement begins with Patricia making a suggestion to add another large gear to the string of four gears on three axles that they already have. The gears are set up as follows: first axle a large, second axle a medium touching the large and another large touching the medium gear on the third axle. Kenny disagrees and asserts an alternative position, saying it will go more slowly. Filene, locates the evidence that, in any case, there are no more large gears in their storage box. This is a move towards a resolution. This is then followed by a series of resolution moves during which Patricia proposes alternative possibilities and Kenny continues his initial opposition. The disagreement terminates with Patricia making and executing a new suggestion while Kenny and Filene get distracted.

In this example, the cognitive move reflects what each child has done from his or her individual perspective, in light of what the others said and did during social interaction. The first utterance (0), from a social perspective, was an antecedent to the disagreement. Looking at this same event, only this time from the individual's cognitive perspective Patricia has initiated a topic to their discussion. Kenny (2) from the social perspective, opposed Patricia, while from a cognitive perspective, he has added a new aspect to the discussion. Filene (3) in an attempt to resolve the disagreement, added a new aspect (that there are no more large gears). This was followed by Kenny who continued to oppose, but from a cognitive perspective has modified his position to take into account Filene's contribution. The disagreement continues with another resolution move (4) and opposition (5) during which, Patricia and Kenny each added new information about the topic being discussed. Filene (6) provided an example of integrating another participant's position while Kenny (7) continued to maintain his position and Patricia added another new information.

2.2. Analysis and a summary of some of the results

In order to gain more insight into the process of collaborative learning, the children's social and cognitive moves were examined from three different perspectives. These are independently, in parallel and sequentially. Each perspective sheds a different light on the process. Looking at the moves independently reveals the composition of the disagreements from a social and cognitive move perspective. In parallel, it reveals the cognitive moves taking place during the social moves. Sequentially it allows one to see if certain moves incite others during the disagreements.

A total of 24 substantive disagreements were identified while working on their second invention that covered a 5 week period. The results indicate that:

- The children were able to discuss, defend, modify and actively seek solutions during disagreements.
- The children did more than oppose each other. They attempted to resolve their oppositions.
- The opposition during a disagreement was more than negation. The children insisted on explanation and evidence as they worked on their shared task.
- The resolution process of the disagreements included integrating other children's ideas, modifying their own ideas and asking others for clarification and explanation.

3. Conclusion

The proposed analytical framework that looked at social moves and cognitive moves from a parallel perspective proved to be very useful for gaining access to the collaborative process while learning. Although an extreme case of collaboration was used in the application of this framework, it served well for demonstrating the power and the potential of this approach. Clearly, the framework needs further development to be able to accommodate other types of collaborative interaction. As suggested in Roschelle's (1992) study and now in this one, the notion of simultaneously looking at the same act but from different perspectives seems an interesting approach to furthering our access and, in turn, understanding of the collaborative process.

The conclusions with respect to the collaborative process and children's disagreements suggest that a) children's disagreements can be viewed as a legitimate source of collaboration and b) children's disagreements can be both constructive and productive in the learning process. Children's disagreements appear to hold an important role in active learning. How we accommodate these, as well as other types of collaborative interaction, is an important consideration for future research on learning. As we broaden the scope of collaborative learning together with the CSCL environments to support it, we need to enhance the ways in which learning is understood.

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The Knowledge Integration Environment: Theory and Design

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Abstract

The Knowledge Integration Environment (KIE) combines network resources and software with sound pedagogical principles to improve science learning. KIE networking tools allow students to use scientific evidence in activities that foster knowledge integration. In a pilot test in an eighth-grade physical science classroom, students worked collaboratively to answer scientific questions such as whether light travels forever or dies out. With the KIE, students use evidence from the Net and tools such as an electronic notebook and on-line discussion tools to make collaborative decisions. This paper describes the pedagogical framework, the components of the KIE software, and initial results from pilot research. We conclude by discussing promising next steps for networking in science education.

Keywords — science education, networking, Internet, K-12 educational technology, computer learning environments, scientific evidence, collaborative learning environments.

1. Introduction

The Knowledge Integration Environment (KIE) project draws on technical, cognitive, and social resources to create a productive electronic learning community. We seek to design a learning environment that helps K-12 students use the as-yet untamed (and growing) Internet to acquire skill in interpreting scientific material, gain an integrated understanding of complex scientific ideas, and develop a propensity toward integrating knowledge in general. As more and more schools connect to the information highway, the need for learning environments increases. Such environments take advantage of the corpus of "classroom materials" that are added to the network daily and allow students across the nation to work together to investigate scientific problems.

In this paper, we describe the goals and motivation for the KIE project, delineate the framework that guides this work, describe the preliminary design of the KIE, and summarize our pilot investigation. In conclusion, we describe future directions for creating electronic learning communities.

1.1. Motivation and Goals

The project is exploring how exciting and rapidly expanding new electronic tools, network resources, and human resources can jointly improve science learning and instruction. At present, Net[1] resources are underutilized and tools are inadequate, often limited to browsing without direction. The Net includes a broad array of scientific information that could be tapped to improve science education.

Educators and researchers agree that students need connected ideas, not isolated, inert knowledge. Yet students encounter topic after topic in science classes. National standards and state frameworks encourage integrated understanding, but list more topics than most students can integrate. When there is not enough time to get into a topic deeply, students become accustomed to looking at things superficially. Furthermore, incentives to integrate knowledge are few. Standardized tests generally assess isolated facts, and classroom tests often mimic standardized tests.

The material taught in science class is often too abstract for students to understand. Students need models that are appropriate for them, problems that are relevant to their lives, and guidance to help them develop an integrated understanding.

Teachers often understandably rely on tried-and-true methods, such as using lectures and textbooks, which can promote beliefs of "teacher or book as authority" and "science as a static field" instead of the active, understanding-focused learning and dynamic view of science that we would like students to see as they participate in science classes. To remedy this situation, the KIE software and curriculum helps students use the Net to work on large projects designed to help them integrate their ideas.

1.2. Using the Net for Learning

Research is needed to determine productive ways to take advantage of the Net connections to pre-college institutions. We need to develop good models for effective instructional uses of this resource. The Kids as Global Scientists project and the Collaborative Visualization project provide two examples of such models (Pea, 1993; Songer, 1993). In both cases, use is targeted primarily at questions involving the weather. We take a broader approach, seeking ways to help students draw on diverse information as they make sense of science.

How can we create an instructional environment that helps students develop the integrated understanding of science that they need? We discuss instructional, cognitive, and social issues.

In instruction, the Net has the potential for perpetuating or exacerbating the emphasis on breadth over depth in science. If students browse without a goal, their exploration may resemble channel surfing. Indeed, the Net can provide hours of entertainment. However, students need activities and resources that help them benefit from their investigations. The Net provides plenty of opportunities to look at or read material, but not as many opportunities to link and connect ideas. KIE provides activities for active, engaged learning.

From a cognitive perspective, students need scaffolding for navigating and searching on the Net, and they need guidance to determine what is worth paying attention to and what should best be ignored. KIE provides tools to make the Net more manageable, and begins a process of developing resources on the Net which are useful to students.

Making the Net a socially meaningful experience requires careful software and curriculum design. Working on the Net can be a very isolating activity. Interactions are not common among those providing information on the Web and those browsing that information. In fact, using the Net does not have to be collaborative at all. KIE promotes collaboration among students through its software design and curriculum structure as described later in this paper.

Furthermore, according to a recent study, about 90% of current Web users are male, and 87% describe their race as white (Pitkow & Recker, 1994). The Web must be made a more female- and minority-friendly place if it is to be of widespread benefit.

2. Scaffolded Knowledge Integration

To make the Net an effective and efficient tool for learning, KIE follows the Scaffolded Knowledge Integration Framework (Linn, 1995; Linn, Songer, & Eylon, in press). This framework synthesizes over 10 years of research on science knowledge integration. We describe the rationale, goals, and components of the framework.

The Scaffolded Knowledge Integration framework responds to research showing that science courses confuse students by contradicting "everyday" observations (Carey, 1985; diSessa, 1993; Resnick, 1983; Vosniadou & Brewer, 1992). Rather than changing their ideas, students respond to these contradictions by concluding, for example, that objects in motion come to rest at home but not at school, or that light dies out at home but not at school, or that heat and temperature are the same at home but different at school. To support knowledge integration, science courses must help students reconcile scientific models and intuitive observations, and guide students to distinguish technical and colloquial usage of science vocabulary. To help students gain a robust and predictive understanding of science, the Scaffolded Knowledge Integration framework emphasizes making connections between scientific concepts and relating these concepts to personally relevant situations and problems. The framework suggests guidelines for designers creating science learning environments such as KIE.

The Scaffolded Knowledge Integration framework helps students distinguish and connect their models of the scientific world. We view science learners as exploring and modifying a repertoire of models (Linn, diSessa, Pea, & Songer, 1994). Science is a dynamic process, nobody yet has found "absolute truth" in a single model or theory. Scientists enjoy testing, revising, and re-evaluating models of scientific events. To help students become lifelong learners and to prepare them for the vast array of models they might encounter when searching the Net, we can let them join in the fun of testing, revising, and re-evaluating models.

In science classrooms, we find a plethora of alternative scientific ideas: models that the teacher and textbooks provide and ideas which students bring when they enter the science classroom. We hope that instruction will encourage students to consider, besides their own ideas, others that are useful and close to currently accepted ideas. The Scaffolded Knowledge Integration framework guides designers to create activities and tools that develop the abilities of students to sort and distinguish among a multitude of ideas. The purpose of science instruction, then, becomes to find the best mix of models for the students, to ensure the presence of these models in the science classroom, and to engage students in analyzing and connecting these models.

The Scaffolded Knowledge Integration framework has four main components: (a) identifying new goals for learning, (b) making thinking visible, (c) encouraging lifelong learning, and (d) providing social supports (Linn, 1995). As mentioned above, the first component involves introducing a mix of models that build on student intuitions and encourage testing, revising, and reformulating scientific ideas. Providing models is not sufficient for knowledge integration. Students need to understand the process of thinking about alternative models and they need support so they can do this independently.

The second component of the framework, making thinking visible, emphasizes making alternative models accessible to students. Students need to understand several perspectives on scientific ideas in order to experience the fun of comparing and testing scientific ideas. Students also benefit when the actual processes of comparing scientific explanations, models, or theories are made visible. This might happen when two students debate about theories or when students read a debate between two natural scientists. Making thinking visible is not sufficient, however, since students also need to take responsibility for reaching their own conclusions in order to become lifelong learners.

Thus, the framework includes techniques for helping students reflect on their own ideas, and monitor their own performance. One approach is to engage students as investigators and critics of science.

The final component involves orchestrating productive social interactions in the classroom while guarding against situations which would support gender stereotypes or status effects (Linn & Burbules, 1993). Students can help each other compare ideas and link models when they respect each other.

By focusing on how models of scientific phenomena can be compared, by helping students distinguish among the models that they currently hold, and by emphasizing that scientists engage in this process of distinguishing and selecting models for scientific phenomena, the Scaffolded Knowledge Integration framework provides a firm foundation for students planning both scientific and non-scientific careers. Furthermore, as citizens make more and more use of the Net, they will need skills in distinguishing among models and selecting information relevant to their own ideas. KIE, by following the Scaffolded Knowledge Integration framework, will help students develop skills they will need throughout their lives, and also provide tools for the development of integrated understanding of complex scientific material.

3. KIE Curriculum and Pilot Study

We have developed KIE software and activities which have been tested with middle school students. This section describes the KIE activities and the pilot investigation. The next section gives details of the software design.

The KIE curriculum consists of activities that help students develop (a) the ability to critique evidence, (b) a propensity toward knowledge integration, and (c) an integrated understanding of science topics. To achieve integrated understanding, KIE activities emphasize depth rather than breadth. To ensure that students become independent learners, KIE activities scaffold and support students as they refine their scientific ideas. Since the Net lacks organization, KIE provides a structure for building collections of Net evidence and prompts students to systematically search for information relating to their projects.

In addition, KIE tools guide students to use the Net effectively rather than mindlessly browsing or superficially covering many topics. Students can use KIE tools for classroom activities and on personal investigations or projects. Looking at information on the Net is necessary but not sufficient to complete a KIE project. Students must analyze evidence, producing scientific explanations for real world phenomena. In doing so, they interact with a larger community of science learners. This community ranges from their schoolmates in other class periods of the same science course to natural scientists across the globe. The scaffolding helps students use specific evidence and also models the type of thinking appropriate for knowledge integration.

3.1. How Far Does Light Go?

As part of the KIE pilot study, students engaged in the "How Far Does Light Go?" project (described in Bell, 1995). The activity helps students integrate their knowledge by contrasting two theoretical positions about the propagation of light using evidence from both scientific and everyday sources. One position that students support is the scientifically normative view that "Light goes forever until it is absorbed" while the other is the more phenomenological perception that "Light dies out as you move further from a light source."

Students begin the activity by stating their personal position on how far light goes. Then they review evidence on the Web and determine whether each piece supports, contradicts, or is irrelevant to their position. Students next engage in a brainstorming activity to create pieces of evidence to bolster their argument by pulling from experiences in their own lives. Students can make the evidence they create available to all class members over the Net. The students then synthesize the evidence and formulate a scientific argument supporting one of the two theoretical positions. As they carry out these steps, the software scaffolds them by providing guidance and prompts. Student teams present their arguments in a classroom discussion and respond to questions from the other students and the teacher. Finally, students reflect upon issues that came up during the activity and once again state their position on how far light goes.

3.2. Methods

We tested the "How far does light go?" activity with 165 students in a classroom using the Computer as Learning Partner (CLP) curriculum. In this eighth-grade physical science class, students learn from laboratories rather than lectures or texts. The class studies energy: thermodynamics, light, and sound are the topics. For KIE activities, students work in groups that function as research teams. In the pilot study, they worked in pairs on the 16 available computers. Each randomly-assigned pair jointly conducted all aspects of the activity using a single computer. The KIE software has been designed to support groups of varying sizes to accommodate the differing availability of technology in schools.

We compared the KIE implementation of the "How Far does light go?" activity to the off-line version of the activity that students had used the previous semester. The KIE version (a) provided richer, multimedia evidence than the text-based evidence used in the off-line version, (b) supported students with on-line guidance, augmenting the assistance coming from the teacher, and (c) guided students as they completed each part of the activity with a checklist that indicated completed work and next steps.

3.3. Preliminary Results

Several benefits of KIE are apparent in initial analyses of the pilot study data. In addition, pilot test results suggest ways to improve the KIE software.

First, students worked productively with the software environment and within the activity structure provided. Student groups by-and-large made progress on their projects of their own accord and produced project work comparable to or better than in previous semesters according to holistic measures. In spite of the efforts necessary to learn the software, students could use it as intended.

Second, students worked with evidence differently with KIE than they had in previous semesters using the off-line version of the activity. In comparing their categorizations of identical pieces of text-based evidence, students connected more of the evidence to the debate than they had previously. This supports the conjecture that the KIE can be used to productively engage students in linking evidence to theories.

Some of the students were randomly assigned richer, multimedia versions of the evidence. For example, some students read text describing how telescopes can be used to see more stars in the night sky, while others viewed an image depicting the night sky with a blown-up insert of the corresponding image captured by the Hubble space telescope. Students treated the text and multimedia versions of the evidence differently. Thus, 75% of the students categorized the text version of the telescope evidence as supporting the "light dies out" position, while 65% found that the multimedia version supported the alternate "light goes forever" position. Students often connected multimedia evidence to different theories than the corresponding text evidence.

Third, trials of the guidance for KIE projects suggested revisions for the next version. Students used the procedural guidance to determine what to do next as they carried out their projects. Cognitive guidance, encouraging students to consider alternatives, reflect on their conjectures, or evaluate their progress was largely ignored. As a result we are designing more specific cognitive guidance and also altering the interface to make this guidance more prominent.

Overall, the pilot study demonstrated the feasibility of the KIE approach, suggested directions for further research on the role of multimedia evidence, and motivated improvements to the curriculum and the software.

3.4. KIE Dissemination Plans

We will provide the KIE software and curriculum to schools wishing to help us improve the materials. Dissemination to multiple schools allows students to collaborate with others electronically. Students can post information or data to the Net and participate in on-line discussions of activities. Teachers, too, can work with remote colleagues, exchanging curriculum materials, pedagogical knowledge, or technical advice. In addition, KIE could be used by learners at home and by individuals doing school projects.

4. KIE Software Design

The KIE software includes commercially available tools and project-developed materials. Commercial components include:

- *World-Wide-Web Browser*—which provides an appropriate graphical interface for evidence on the Net;
- *HTML Editor*—which allows students to create and edit multimedia documents for the Web; and
- *E-Mail Software*—which allows students to send and receive electronic mail with other individuals.

KIE also features the following project-developed software components (described subsequently):

- *KIE Tool Palette*—a constant interface component that affords navigation of the system components;
- *Netbook*—a Net-oriented notebook that allows student groups to organize, analyze, and author evidence;
- *Networked Evidence Databases (NED)*—collections of scientific evidence both from the Net and created by students, organized by science topic and activity;

- *SpeakEasy*—a multimedia discussion tool which allows students to conduct structured conversations about their scientific ideas over the Net;

- *Student Knowledge Integration Planner and Profiler (SKIPP)*—a teacher tool that allows users to design and orchestrate Net-oriented activities for their students, as well as identify and customize activities for individual students based on their proficiencies and interests; and

- *Knowledge Integration Coach (KIC)*—an on-line guidance system which provides supporting prompts and feedback as students work on activities.

4.1. The KIE Tool Palette

At the start of class, each student in a group logs onto the KIE system. A palette is displayed that allows students to navigate between the different software components of the KIE system and to ask for guidance (see Figure 1). Additionally, the KIE Tool palette allows students to save a bookmark, the text, or a screenshot of something on the Web to their group notebook (discussed below). Students can alternatively save references to Web pages into different categorical groups. For example, in the "How Far Does Light Go?" project, students categorize a set of evidence from the Net as to whether it supports, contradicts, or is irrelevant to their stated theoretical position.

4.2. The Netbook

The Netbook allows students to collaboratively manage their projects and documents, as well as become authors on the Web (see Figure 1). A Netbook is opened for the team as they log onto the KIE system, providing access to their current and past work. This software uses a notebook metaphor to provide students with access to all of their projects (as tabs into the notebook), the sections within those projects (as folders within each project), and all of the documents that make up each of those sections. Students can create, open, or delete any of the Netbook elements.

The Netbook has been explicitly designed to simplify analyzing and authoring World-Wide-Web documents. It functions as a jumping off point to a Web browser, HTML editor, word processor, and other multimedia authoring tools. (Currently, KIE utilizes the Netscape Navigator™ software for web browsing and the ClarisWorks™ integrated application package for authoring Web documents using the Web-It™ module (Soloway, 1995).)

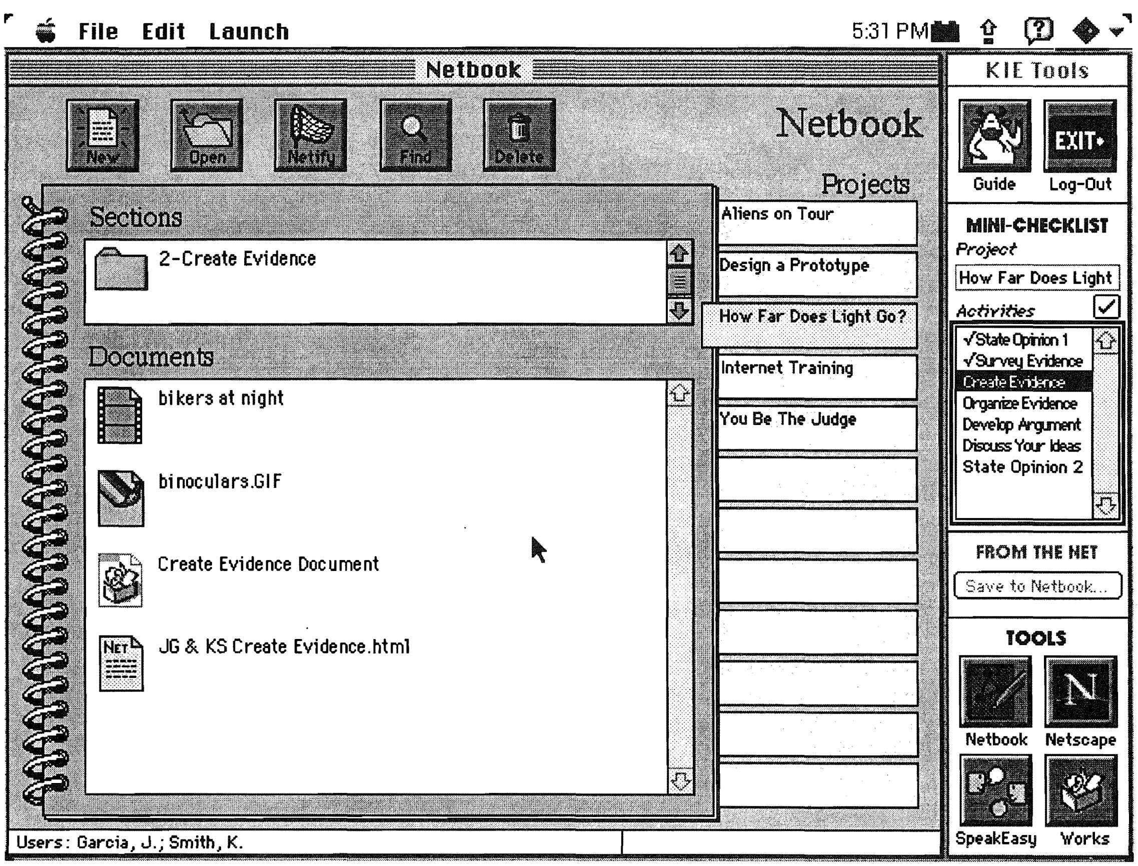

Figure 1. The Netbook and KIE Tool Palette.

4.3. The Networked Evidence Database (NED)

The World-Wide-Web allows individuals to organize existing information resources from around the globe into new representations. For example, an inspired student can take information relating to home insulation and turn it into an information resource on the Web structured by geographic area. As part of the KIE curriculum framework, we have designed and implemented a Web-based database structure composed of scientific evidence to be used by students in KIE activities.

The Networked Evidence Database (NED) is a collection of individual pieces of evidence, where each piece has been cataloged and described using a set of identifying characteristics (e.g., the type of evidence, the author's motivation and methodology in producing it, representative keywords, and a list of KIE activities for which it may be appropriate). Figure 2 shows a piece of "everyday" evidence that relates to the science topics of light reflection and absorption, light intensity over distance, and vision. It shows frames from a digitized movie of two bicyclists, one wearing black and one wearing white, riding up a street at night.

The NED is composed of evidence that has been created explicitly for use as part of KIE, as well as additional appropriate evidence that already exists on the Net. Submissions to the NED can come from the KIE Research Group, natural scientists, teachers, and the students themselves. As part of the KIE activities, students collaboratively engage in the creation of evidence to be published in the NED, drawing on the scientific methods and experience they may be engaged in as part of classroom laboratory or research activities. For example, a student team may author a piece of evidence summarizing a lab they performed in class or they may make a digital movie of a particular phenomena. Alternatively, evidence may come from newsgroup discussions taking place on the Net or from other information resources on the Web.

4.4. The SpeakEasy

The SpeakEasy is a tool for discussion and collaboration across the Net about multimedia materials contained in the NED. The SpeakEasy interface is based on a prior tool for collaborative learning in multimedia, the Multimedia Forum Kiosk (Hsi & Hoadley, 1994). Using the SpeakEasy, students record their opinion and participate in a discussion summarized in an argument map. The multimedia interface with images, texts, sound, and video has been tested and found helpful in stimulating productive discussion and reflection (Hoadley & Hsi, 1993).

Although not used in the pilot study, the SpeakEasy allows multimedia discussions over the Net. Teachers can request that a topic be set up, list the students permitted to interact or leave the conversation "open to the public", and attach multimedia materials to their topic. Students are then able to leave their

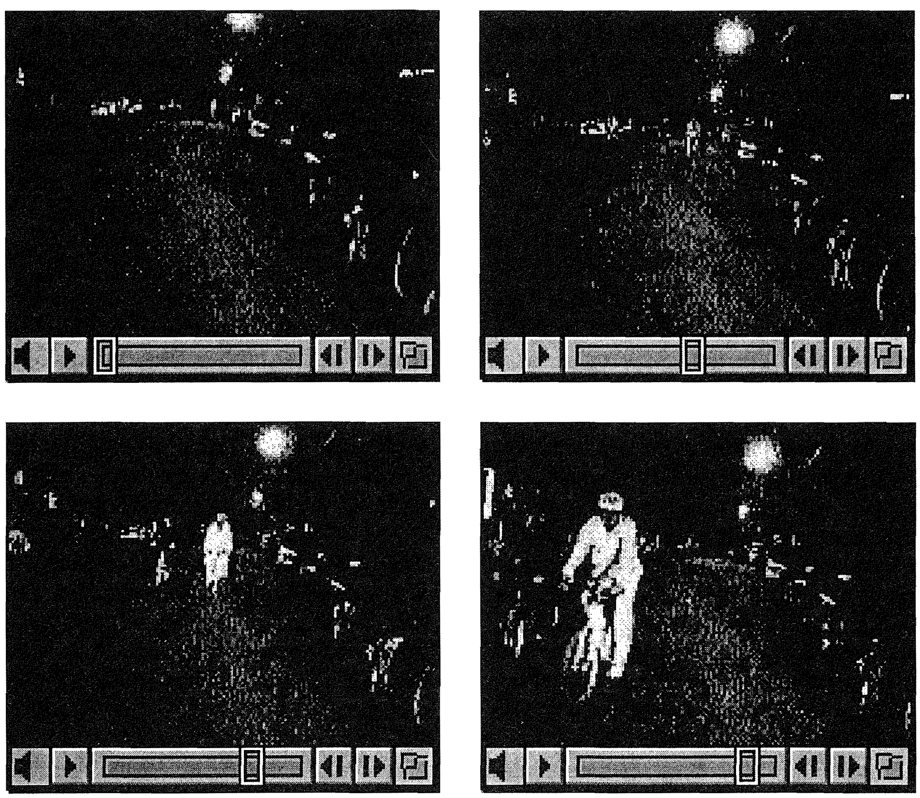

Figure 2. Frames from the "Bicyclists at Night" Evidence.

opinions and interact with other students by responding to their comments. The results are organized by individual viewpoint or by a diagrammatic representation of discourse. Students summarize the SpeakEasy discussions and add these to the NED. Discussions will be equally easy within a local site or between remote sites around the world.

4.5. Student Knowledge Integration Planner and Profiler (SKIPP)

The Student Knowledge Integration Profiler and Planner (SKIPP) will be comprised of two primary parts: an activity planner and a student profiler. The pilot study allowed us to refine the SKIPP data structure necessary to support having students work through various KIE activities.

The activity planner is used to manage a set of KIE projects, each of which has associated activities, which in turn have associated documents for student work, and guidance for students as they work on the project or activity, as well as lists of relevant and appropriate evidence. Furthermore, within the activity planner, teachers can design their own projects, or modify existing projects. KIE projects can be easily imported and exported from the SKIPP, allowing projects to be exchanged over the Net through a curriculum library.

The student profiler keeps track of the projects and activities each student has completed, as well as the evidence they have seen. The student profiler also provides an entry and storage location for student interests, preferences, epistemological beliefs, and knowledge about the scientific material. This information can then be used to allow projects and activities, as well as feedback, to be customized to particular student needs using the KIC.

4.6. The Knowledge Integration Coach (KIC)

One of the most important inputs to the SKIPP will be the guidance used by the Knowledge Integration Coach (KIC). The KIC provides guidance at three levels. Project-specific scaffolding guides students to think about what is the main idea they should keep in mind as they work on the various activities and look at the evidence for a particular project. Activity-specific hints help students as they work on a particular aspect of the project. For example, the student might be reminded of the goal of writing a critique of a piece of evidence, and what is appropriate to include in such a critique. Evidence-specific hints guide the student to critically evaluate evidence in the NED. All of these levels of scaffolding model appropriate modes of inquiry. They also provide stepping-off points for students to engage in meaningful discourse with their peers about particular activities or evidence. These hints are intended to help students develop an integrated understanding of the subject matter by encouraging them to produce personal explanations (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989).

5. Future Directions

The KIE project has several current goals. First, to make the KIE tools transparent and self-instructional we plan trial-and-refinement studies with a broad, representative range of users. Results from these studies guide revisions that make KIE flexible and easy to use for both students and teachers.

Second, to implement the Scaffolded Knowledge Integration framework KIE must provide effective guidance for students. We plan research on how best to guide students. Students can currently choose the amount of guidance that they want the KIC to provide. Instead, we might diagnose student guidance needs and personalize guidance depending on how students organize the materials they access. For example, we can use information in the SKIPP to personalize guidance from the KIC. We plan to research options for providing "meaningful" feedback and guidance.

Third, access to networked materials increases the importance of helping students assess the validity of evidence. When texts are the main source of scientific information students tend to accept statements uncritically. Results from our pilot studies indicate that students often extend this disposition to other materials they encounter in science classes. Since some networked materials are intended to persuade rather than inform and others are opinions rather than results from investigations, students need to develop skill in evaluating evidence. We plan to examine how students evaluate communications from peers, from newspapers, and from other sources to develop effective guidance for assessing networked materials.

Fourth, the KIE has the potential of fundamentally changing classroom activities and extending science learning into homes and other settings. We plan to study the new activities that these resources enable. We wonder which students will benefit the most from alternative environments for science learning. We will seek ways to use these technologies to motivate students who have lost interest in science.

The increasing availability of Net resources challenges educators to create a global community of science learners, to connect students to dynamic, ongoing science explorations, to communicate the nature of science as well as the concepts of science, and to sustain interest in science. The Scaffolded Knowledge Integration framework can help make the Net a partner in science learning. Ultimately, this framework and the KIE can help students develop a lifelong habit of science exploration sustained by Net resources.

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Additional information on the KIE project is available at "http://www.kie.berkeley.edu/KIE.html" on the World-Wide-Web.

[1] Throughout this paper, we use the term "Net" to indicate global networking technologies, including the current Internet and the World-Wide-Web. When we explicitly reference the Internet or the World-Wide-Web, we use those more specific terms.

Computer Conferencing and Collaborative Writing Tools: Starting a Dialogue About Student Dialogue

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Abstract

Calls for a more "learner-centered" curriculum is heard from the pulpit of most educational reformers of the 1990's. In response, this paper explores the Collaborative Writing (CW) tools available for different levels of electronic interaction that might be indicators of high quality social interaction. In a series of studies starting in late 1993, a research group at Indiana University began to demonstrate how different CW tools and formats impact social interaction and learning. This paper discusses these efforts in terms of the age level of participants, tool utilized, and instructional strategy or task. CW tools reviewed here are categorized into five levels ranging from electronic messaging to delayed collaboration tools to brainstorming tools to real-time collaborative writing tools to collaborative hypermedia. Though the review of these tools is important, a survey of coding schemes used to analyze electronic transcripts point to the forms of teacher or peer assistance, levels of questioning, degree of perspective taking, status, content talk, peer feedback, and types of scaffolding available over computer-mediated communication. Transcript codings and findings across these electronic social interaction studies point to some commonalities in effective instructional use of these technologies as well as the means to analyze the salient discourse processes and sharing of meaning.

Keywords — collaborative writing, dialogue, sociocultural theory, computer-mediated communication, computer conferencing.

1. Introduction

Research in the social context of learning has provided substantial support that traditional teacher-centered instructional approaches must be replaced with more active, learner-centered environments (Alexander & Murphy, 1994). As educators push for more active learning opportunities, Vygotsky's (1986) sociocultural theory of cognitive development is rapidly influencing diverse educational arenas. Vygotsky's tenets about learning and development emphasize the importance of social interaction with adults and more capable peers as a means to guide children to developmental levels they might not independently attain (Brown & Palincsar, 1989). Recent CW studies provide support that students' internalize the scaffolding of more capable peers when collaboratively writing (Daiute & Dalton, 1988) as well as the cognitive supports or prompts provided by computer tools (Salomon, 1988).

Though educators are turning to Vygotskian writings to promote the social context of student learning (Tharp & Gallimore, 1990), researchers have yet to make significant in-roads regarding how cognitive processes displayed on a social plane become internalized by the participants (Wertsch, 1991). Ideas about student zones of proximal development, scaffolding, and internalization remain difficult to implement. Educational researchers continue to struggle with the new focus on activities and event meanings as the unit of analysis. Analyzing electronic social interaction is no different.

Despite these theoretical struggles, CW and computer conferencing tools clearly can help us create these learning environments. As the formats for electronic collaboration proliferate, computer conferencing has great potential for changing the ways students and their instructors interact with each other and organize their learning processes. To make decisions that productively transform learning environments (Schrage, 1990), therefore, research is needed that records how schools, teachers, and students are discovering, employing, and modifying the numerous new CW tasks and tools.

2. Collaborative Writing Roadblocks

There are a numerous obstacles facing the study of computer conferencing and CW. Researchers, in fact, have just begun to examine the social interaction differences between CW tools such as computer network technologies and traditional writing classrooms (Forman, 1992). Minimal documentation presently exists regarding the differences in communication patterns, teacher roles, or student writing performance across levels of CW tools and tasks. Many questions remain:

- Will CW foster new expectations of teaching?
- What types of writing collaborations are preferable to teachers and students? And when?
- What kinds of CW activities are facilitated by different writing tasks and tools?
- How do students assist each other during CW?

These questions unfortunately are often forgotten when viewing ingenious writing technologies or hearing about the exciting, new features for searching and sharing knowledge. Our research group has attempted to overcome these barriers by demonstrating how different CW formats impact social interaction and learning.

3. A Collaborative Writing Taxonomy

Bonk, Medury, and Reynolds (1994) defined CW as groups of two or more people working in concert on a common text project in an environment supportive of their text and idea sharing. In providing that definition, however, we realized that CW tools currently offer a maze of new communication channels among participants (from one-to-one, many-to-one, and many-to-many) and a range of text support (e.g., electronic mail, delayed collaboration, brainstorming, and real-time text collaboration).

After surveying and testing a number of CW tools, Bonk et al. (1994) attempted to clarify this predicament by designing a taxonomy of five levels of CW tools for school learning (i.e., from electronic mail to real-time text document sharing; see Appendix A) as well as a model of the levels and types of nonacademic writing support tools (Bonk, Reynolds, & Medury, in press). Though many similarities are evident, the diversity of activity settings and coding schemes continues to challenge educational researchers and are roadblocks in movements to reform education from a social constructivist framework. The next section provides the specifics of our CW efforts to date.

4. Researching the CW Levels:

From a series of studies, we have discovered that these tools can: (1) change the way students and instructors interact; (2) enhance collaborative learning opportunities; (3) facilitate class discussion, and (4) move writing from solitary to more active, social learning. By examining the CW formats used in schools and universities, our research projects to date reaffirm our taxonomy of CW tools used in schools (see Appendix A) and help us refine and reevaluate our coding schemes for CW dialogue. These results should inform researchers, tool designers, and policy makers of the importance of social interaction and dialogue in various CW tools and tasks.

4.1. Level I: Electronic Mail Tools

The **first study** was conducted in a course that was project oriented and met for three hours, once a week. In this course, two professors interacted with 48 students organized into 12 different teams, each working on separate and unique projects. To maintain contact with each student and track their progress, students were required to complete weekly reports and e-mail them directly to the instructors. The instructors then responded to each student with an individualized e-mail message which was coded during the semester. The interaction categories were based on the six "means of assistance" identified by Tharp and Gallimore (i.e., modeling, contingency management, feeding back, instructing, questioning, cognitive structuring; see Tharp & Gallimore, 1988). E-mail was more prevalent in the beginning of the semester and primarily performed a feedback function.

The **second project** analyzed involved a two semester graduate course sequence taught by the same instructor (one course was more hands-on/design related (i.e., hypermedia) and the other was more theoretical in nature (i.e., constructivism)). The first part of the sequence was a discussion class in which class and e-mail participation was graded, while the second part of the course was project-based. Rich data was obtained from following the e-mail conversation for the entire year in order to determine the role it played in the learning environment, the social interactions that occurred, and how this form of computer mediated communication can best be used to support learning. Coding schemes by Tharp and Gallimore (1988) and Granott (1991) utilized for this analysis indicated that E-mail was more prevalent in the design class; however, in each class, the instructor dominated e-mail discussion.

4.2. Level II: Remote / Delayed Collaboration

The **first of many delayed collaboration projects** involved a common and effective on-line communication tool (i.e., the *Internet*) (see Harasim, 1990). In this study (Sugar & Bonk, 1994), "telecommunities" and cognitive apprenticeships (Collins, Brown, & Newmann, 1989) provided students the opportunity to have new "pen pals" and fostered common understandings or new perspectives among themselves; what Riel (1993) refers to as a global education. The World Forum, developed by the University of Michigan, is an on-line asynchronous telecommunications project designed to give students from six middle and six high school classrooms the opportunity to interact with each other about critical environmental issues. Throughout these interactions, the student groups are assisted by WorldForum mentors who question and guide the student groups' understanding of these environmental issues. Tharp and Gallimore's (1988) six means of assistance (noted earlier), Bloom's (1956) levels of questioning taxonomy, and Selman's (1980) degree of perspective taking developmental scheme were used to map out these interactions. In the World Forum component of the World School, students discussed, questioned, and debated with Arctic explorers, mentors, and peers about environmental issues. Student role taking activities within these environmental discussions (students assumed roles of famous people like Professor Stephen Jay Gould and Mr. Richard Leakey) enhanced the degree of perspective taking in their conversations. This finding was interesting since mentor assistance and scaffolding during these exchanges was minimal.

The **second Level II project** discussed here involves a distance learning course entitled, Interactive Technologies for Learning, using picture-tel technologies to deliver the course. Here, the instructors at each site utilized electronic conferencing methods to organize, control, and facilitate electronic discussions and meaning negotiation. The analysis here is used to determine whether the instructors successfully assumed the role of student mentor and guide. Each week, students were involved in discussing the articles for the class. "Starters" were used to summarize the articles and begin discussion of the articles and open questions, while "wrappers" were used to summarize the discussion that took place. During the intervening days, students participated at least once on that conversation. Student VaxNotes were analyzed into categories like questions, clarifications, and answers. In addition, the relevancy of the comment to the topic and contribution to the construction of meaning was noted. Instructor VaxNotes were sorted according to instructional planning, commenting, and guiding.

A **third Level II project** investigated computer conferencing using a new tool, *First Class,* within a computer network. *First Class* allowed multiple users to communicate with each other regardless of time or geographical location, thereby fostering discussion threads on any topic of interest.

4.3. Level III: Real-Time Brainstorming

In Level III, multiple users can simultaneously brainstorm by sending messages to each other. In the only study noted here, we created several teaching dilemma prompts for preservice teachers to resolve electronically while working in subject matter teams (e.g., science) in either real-time or delayed formats. One class of 30 preservice teachers in an educational psychology class interacted over *VAX Notes* in the Electronic Classroom (EC) (i.e., the delayed, asynchronous setting), while two other classes interacted using "*Connect*" (i.e., the real-time, synchronous setting). Naturally, issues of group size, roles or participant structures, and task requirements (e.g., length) are critical to the effect of these tools. Coding of student dialogue transcripts indicated that role assignment was critical to group intermental processing and attitudes. Whereas the use of the synchronous software tool, *Connect*, increased the range of possible group assignments and interaction patterns, the analyses also illustrated that asynchronous communication (Level II) facilitated more serious and lengthy interactions than those in real-time over a local network (Level III; i.e., synchronous communication). After developing a coding scheme for student-student interaction patterns in CW and electronic mail based on Meloth and Deering (1994), the dialogue transcripts revealed that the delayed collaboration mode resulted in more thoughtful and extended peer interaction patterns.

4.4. Level IV: Real-Time Text Collaboration

Real-time collaborative tools allow students to view changes that peers and colleagues make to a document as they are being enacted (see Level V study below and Appendix A for examples).

4.5. Level V: Cooperative Hypermedia

This final level involves real-time collaboration on a common text or graphics document. The study reviewed here is of a 10th grade English class studying the Crucible. The teacher incorporates the use of the real-time collaborative writing tool, *Aspects*, to spur classroom dialogue and discourse. An analysis of low and high participating students indicated that collaborative writing software increased the participation rate of quiet students and, to some extent, equalized student interaction patterns. In this study, students interacted using *Aspects* in the free-for-all text mode, in the chat box, and in building common graphic concept maps or webs of knowledge about Crucible characters. On-task behaviors and class discussion were extremely high using this tool.

5. Educational Contribution and Implications

The purpose of this paper is to increase the knowledge base on the benefits and drawbacks of various CW formats by investigating the student dialogue evident in various electronic learning settings. Across these studies of existing CW practices, it is clear that collaborative advanced technologies are important tools for learning. The results indicate that both synchronous and asynchronous computer-conferencing have some advantages over live discussions of cases. CW findings may alter student and teacher ideas about teaching and learning and offer insight into how to use technology as a tool within a learner-centered environment. In effect, our research team has begun to: (1) illustrate how schools and universities are using CW tasks and tools, (2) **start a dialogue about student electronic social interaction and dialogue**, and (3) catalog and inventory specific social interaction patterns within CW. If social interaction patterns and learner-centered ideas embedded in CW are documented and publicized by this research on CW tools and tasks, we will better comprehend and appreciate the components of this new teaching/learning epistemology.

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Appendix A: Taxonomy of Collaborative Writing Tools

(Bonk, Medury & Reynolds, 1994)

Note: the tools listed below may vary in options such as: text outlining, concept mapping, teacher coaching, dialogue tracking, and maximum number of participants.

Level 1. Electronic Mail and Delayed Messaging Tools: allow users to directly send messages or files from one computer to another using point-to-point transfer or to a centralized server using a store-and-forward strategy; while the latter may be preferred since users can log on and off without losing messages, the former may be more economical in a writing lab; useful for assignment reminders, scheduling, and providing document feedback.

cc:mail (cc:Mail, Inc.)

DaynaMail (Dayna Communications)

Microsoft Mail (Microsoft; Note: also has Level 3 applications)

QuickMail (CE Software; Note: also has Level 3 applications)

Level 2. Remote Access/Delayed Collaborative Writing Tools: allow users to remotely access, update, and control files stored on other computers or stored on a mainframe computer; remote access often requires security clearance; helpful for revision or review of a document.

Bank Street Writer III (Scholastic Software, Inc.)

Carbon Copy (Microcom, Inc.)

Collaborative Writer (Research Design Associates)

For Comment (Access Technologies)

Instant Update (On Technology)

Mark-Up (Mainstay)

Prep Editor (College of Humanities and Social Sciences at Carnegie Mellon Univ.)

Prose (McGraw-Hill Book Company)

SEEN (CONDUIT; provides remote commenting on ideas not completed text)

Screen Share (White Knight Technology)

Timbuktu (Farallon, Inc.)

Level 3. Real-Time Dialoguing and Idea Generation Tools: allow multiple users to simultaneously brainstorm on a topic by sending messages to each other; typically have two windows: a shared/transcript window consisting of ongoing dialogue and a private screen for creating and editing dialogue; useful for prewriting, idea generation, and post-writing phases of collaborative writing.

Conference Writer (Research Design Associates)

DIScourse (Daedalus Group, Inc)

Group Writer (Sunburst Communications)

Connect (Norton)

Level 4. Real-time Collaborative Writing Tools (Text Only): allow more than one person to work on a document concurrently; changes to a document are immediately visible to all participants; pointing devices allow users to draw attention to particular parts of a shared document while private chat boxes allow for real-time conversation and commenting; useful for text creation and revision.

Live Writer I (Research Design Associates)

Realtime Writer (Realtime Learning Systems; used mainly for Level 3 purposes)

Level 5. Cooperative Hypermedia Tools: most allow document sharing capabilities of Level 4 above but expanded to other features including: hypertext, graphics, video images, music, speech, or animation; typically require sophisticated hardware; useful for most aspects of writing depending on feature.

Aspects (Group Logic)

CSILE (Ontario Institute of Studies in Education)

HyperAuthor (Hypermedia and Cognition Group at Wisconsin)

IRIS Intermedia (Brown University, Institute for Research in Info and Scholarship)

KnowledgeBuilder (Knowledge Builder)

My MediaText Workshop (K-6) or Mediatext (Grades 7 to Adult) (Wings for Learning)

An Alternative Perspective for Developing a Mathematical Microworld

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Abstract

This article describes one attempt to develop an alternative perspective for designing a computer microworld by using a bottom-up approach to instructional design. This approach differs from traditional instructional design in two ways. First, the program was intended to augment an existing activity sequence rather than serve as an independent environment separated from the students' regular classroom work. Second, it is considered to be bottom-up in the sense that its aim was to engage students in activities that were consistent with their provisional ways of knowing. The first section of this paper describes how the constructs of reification and distributed intelligences were combined with Freudenthal's three design heuristics to guide the development of the microworld. The second section discusses some data from a project classroom in which the program was used.

Keywords — mathematical microworlds, collaborative learning, interface design.

1. An Alternative Approach to Designing a Microworld

The constructs of reification and distributed intelligences offer complementary ways of explaining how learning occurs as students use computers. On the one hand, psychological constructivists such as Kaput [5] suggest that when students are acting on dynamic symbol systems, they are able to reflect on and reify their actions into mathematical objects. On the other hand, Pea [7] assumes a socioculturalist perspective to view learning as a process in which students off-load their lower-level cognitive tasks to the surrounding environment. This off-loading frees the mind to engage in higher-level thinking and planning tasks. From an emergent point of view [1], a coordination of these two constructs suggests that there is a reflexivity between Kaput's view that learning originates in reflection on real-world actions and Pea's view of the computer as a cognitive reorganizer of mental activities.

The purpose of this article is to describe how the constructs of reification [8] and distributed intelligences [7] informed the development and research of a computer microworld. The program, which was developed as one part of a three year teaching experiment, served as one vehicle for exploring the reflexive relationship between the social and psychological components of learning. The guiding theoretical framework suggests that neither individual nor social components can adequately account for learning without considering the other [1]. Therefore, the goal for designing this microworld was to encourage whole-class and group discussions by building an environment in which students could distribute their intelligences to support their individual processes of reification. To this end, the microworld described in this paper offers an alternative approach to design for two reasons. First, it was designed to be used as part of a larger instructional sequence and therefore it was intended to support whole-class discussions rather than being used as a tutor helping individuals who are working alone. Second, it attempts to engage students in activities that are consistent with their current ways of knowing rather than having them interpret expert models. In this way, meanings are seen as emerging through engagement in the social interactions and mathematical practices of the classroom.

1.1. The Candy Factory and the MacCandy Factory

The Candy Factory instructional sequence was first used in a second-grade classroom in Indiana. Reflections on that project were used to inform the development of the present sequence and accompanying microworld which were used in a third-grade classroom in Tennessee. The intent of the sequence was to support students' construction of increasingly sophisticated conceptions of place value numeration and increasingly efficient algorithms for adding and subtracting three-digit numbers. The basic scenario involved students imagining that they were working in a candy factory in which candies were packed in rolls of ten, and rolls were packed in boxes of ten. During the teaching experiment described in this paper, the instructional activity was implemented in three phases. First, students were asked to "pack" and "unpack" Multi-Link cubes to build imagery for estimating quantities. After the students developed a sense of this activity, the first computer microworld was introduced to facilitate the process of packing and unpacking larger quantities. The two goals of this phase of the sequence were to engage students in activities that involved the composition and decomposition of arithmetical units, and to help them develop estimation skills for larger numbers.

The second phase of the sequence involved the introduction of an inventory form to keep track of transactions in the storeroom. The issue of how to record these transactions (and thus the composition and decomposition of arithmetical units) became an explicit focus of the children's activity. Students initially used drawings and other means of symbolizing to model their mathematical reasoning. After the class negotiated a common notation scheme, a second microworld that was consistent with the class's notation was introduced. This microworld contained a linked representation system which provided an opportunity for students to see how their packing and unpacking activities using the graphics were reflected on the inventory form, and, conversely, how changes on the digits of the inventory form were reflected in corresponding changes on the graphics. As a final phase of the sequence, the inventory form was modified and addition and subtraction tasks were presented in vertical column format. After several days of instruction using drawings to support their addition and subtraction models, a third microworld was introduced. This final program was designed to fit with the students' present ways of interpreting adding and subtracting as well as support the development of increasingly sophisticated conceptions.

2. Three Design Heuristics

In order to develop the Candy Factory instructional sequence and the *MacCandy Factory* microworlds, the investigators collaborated with designers at the Freudenthal Institute in the Netherlands. Their approach, entitled "Realistic Mathematics Education" (RME), has lead the mathematics reform movement in the Netherlands. The underlying assumption of this approach is that there is a reflexive relationship between design and research such that each phase informs the perspective of the other. The intent of this collaboration was to coordinate RME's three underlying design assumptions with the sociocultural framework of distributed intelligences [7] to guide the development of instructional sequences and computer learning environments that are consistent with reform-based instruction in mathematics in the United States [6]. The three basic tenets of RME form a strong core of beliefs about mathematics, pedagogy, and mathematics education itself [4]. These core assumptions constitute one example of a unified set of design heuristics that are consistent with the tenets of constructivism [1]. Each of these will be further described below in order to derive a framework for developing and researching other microworld designs.

2.1. Assumption #1: Mathematical learning occurs through mathematization and guided reinvention

This assumption is based on a view of mathematics as an activity rather than a static group of facts that must be assimilated. As students engage in and reflect on their activities, they reinvent mathematical concepts that are personally meaningful. In this way, their mathematical conceptions grow out of their own interpretations of their actions. Gravemeijer [4] uses the term "mathematization" to describe the process by which students begin to develop ways of organizing their situated activities into mathematical interpretations. Although each student interprets his or her activities individually, the teacher can guide this process by encouraging students to discuss their increasingly sophisticated mathematization strategies, with particular emphasis placed on those strategies that are efficient. In the case of the Candy Factory sequence, students' own situation-based activities of packing Multi-Link cubes arose out of their need to count large numbers of candies. Eventually, through whole-class discussions, the students negotiated meanings for the symbols they used to mathematize their activities using pencil and paper. Once these class conventions were established, the teacher introduced the *MacCandy Factory* microworld to support their mathematizing and symbolizing.

In order to facilitate these activities, the computer microworld was designed to include simplistic representations of boxes, rolls and pieces that resembled the students' previously documented notational schemes. The decision to use two-dimensional figures rather than more realistic drawings was deliberately made to support students' understandings of how their own imagery and symbols might be reflected in their microworld activities. Because the icons shown in the microworld were designed to be consistent with the taken-as-shared symbols used in the class discussions, the meanings of the symbols were not assumed to be built into the interface. Further, the interface was not viewed as "containing" meaning, or as a tool for conveying the concept of place value. Instead, it was designed to support students' mathematization activities from the bottom-up; that is, the program was designed to fit with their current ways of knowing and be consistent with the practices of the larger social environment of the classroom discussions.

2.2. Assumption #2: The process of development can be guided by didactic phenomenology

Didactic phenomenology refers to Freudenthal's notion that learning occurs as students create conceptions of mathematical objects by engaging in context problems. Contexts that are described as phenomenologically rich are those which contain situations that "beg to be organized." In the classroom, didactical phenomenology refers to the teacher's sense of how to recognize and capitalize on different students' mathematizations in order to lead to more formal mathematical conceptions. In the present teaching experiment, the program played a role in supporting this mathematization by providing an environment that enabled students to describe their informal strategies so that the teacher could guide discussions toward progressive mathematizations.

One design implication from this assumption is that the development of phenomenologically rich contexts can be informed by two sources, 1) a historical account of mathematics, and 2) observations of prior students' interpretations. These two sources can guide the design process by suggesting possible learning routes to be included in a learning sequence. Additionally, these sources help the designer to focus on the role of the student as an active interpreter. In the case of the Candy Factory sequence, both an historical account of the development of place value and previous research from other teaching experiments provided information regarding how students might develop, interpret, and act on the graphics included in the program. These insights were invaluable as the designers discussed various interface decisions such as the use of arrows and the configuration of the icons in groups of ten. By basing such design decisions on students' interpretations, the designer avoids the top-down assumption that mathematical concepts can be embodied in the software but does create the potential for increasingly sophisticated thinking to emerge.

A second implication from didactic phenomenology suggests that if developers create a virtual world that enables reflection on prior actions and makes alternative actions possible, then students might be able to progressively refine their strategies in sophisticated ways. However, it is also critical to note that many students are not necessarily inclined to develop more sophisticated approached on their own. Nevertheless, such thinking paths cannot be imposed by the program. In contrast, the construct of didactic phenomenology suggests that these processes are socially accomplished as the students and teacher engage in whole-class discussions. For example, as the students and teacher mutually negotiate the sociomathematical norms, efficiency might emerge as an implicit criteria for discussing solutions [2]. Thus, the intent of the *MacCandy Factory* program was to support whole-class discussions, but not to replace the teacher or serve as a tutor with a pre-given instructional route planned out.

One example of how the principle of didactic phenomenology informed the design of the *MacCandy Factory* microworld was the decision of how to handle incorrect answers. Previous experience using the sequence in another teaching experiment revealed that students working with Multi-Link cubes often miscounted as they were packing. As a consequence, the class discussions often consisted of having students recognize their procedural errors. Using the dynamic feedback capability of the microworld, the students' numeric errors were easily caught and rectified. Consequently, the students were able to distribute this low-level counting procedure to the computer so that the class discussions could focus on higher level conceptions such as how packing and unpacking did not change the total number of candies in the storeroom. In this way, the computer supported higher-level discussions in which all students could participate.

2.3. Assumption #3: Self-developed models of actions can be reified to models for mathematical reasoning

This third principle discusses how self-developed (or emergent) models serve to bridge the gap between informal and formal knowledge [4]. When students initially attempt to make sense of context problems, they begin to mathematize their actions by forming models of their informal activity. Through the process of guided reinvention, students' models *of* their informal activities become models *for* more formal mathematical strategies. This approach, which is consistent with Sfard's theory of reification [8], varies widely from a representational view which suggests that students use pre-existing models (such as pre-structured manipulatives) that contain mathematical concepts embodied in their structure [3]. Through a process of reification, meanings and models reflexively emerge as the students engage in the activities and (re)interpretations. Further, if the situations are experientially real for the students, then certain conventions of the models can be introduced because the students understand the need for them. This varies from some traditional instruction wherein certain notation conventions appear (to the students) to be imposed with little rationale.

It may appear incongruous to suggest that students will develop their own models if they are interacting with pre-given representations in a computer environment. Indeed, in many sequences (even those that are not computer-based), the models are not literally invented by the students, but great care is taken to ensure that the models fit with the students' informal activities. This distinction can be used to illustrate the difference between the top-down and bottom-up views. If the students' task becomes one of guessing how the model works, then it becomes a top-down activity, even if this was not the original design intent. In contrast, if the students use the representations to form their own models of their situated activities, then the activity becomes realized in a bottom-up way.

In the case of the *MacCandy Factory*, the intent was that the students' drawings and the icons on the screen could serve as models *of* their situated packing and unpacking activity. As the sequence progressed, these models *of* their actions could become models *for* the more formal mathematical strategies of transforming quantity representations within the base ten system. The working assumption guiding this design process was that the meanings and mathematical understandings could not be conveyed through the program itself. Instead, meanings were intended to emerge from the bottom-up; that is, rooted in the students' models of the context. In this way, their thinking was implicit in their strategies and guided by the activities in which they engaged.

3. Preliminary Findings

Preliminary results from this teaching experiment have revealed that students' models were supported by their use of the *MacCandy Factory* software within the classroom environment. The constructs of reification and distributed intelligences provide insight for guiding our observations of how the students interpreted the activities. For example, after the students became more familiar with the interface, they were able to manipulate and conceptualize increasingly larger quantities of candies. Thus, their efforts to pack the candies were distributed to the computer enabling them to engage in the higher-order thinking skills of estimation and planning. For example, during one whole class discussion, the class debated different strategies for showing the canonical form of 3 boxes, 36 rolls, and 25 pieces by anticipating what would happen if all boxes and rolls were unpacked.

When using the LCD panel to project the *MacCandy Factory*, the type of language used in whole-class discussions shifted from the abstract language of "carrying" to the more concrete language of "packing." Over time, this shift in language reflected the students' shift in viewing the representations on the screen as boxes and rolls to more sophisticated conceptual units. This indicates that students may have been able to reify their models of packing and unpacking to develop increasingly sophisticated models for place value numeration. For example, several students developed the ability to estimate large quantities by building on their imagery of the conceptual units in the candy factory.

One of the most frequent topics of conversation centered around negotiating various notational schemes. It became evident that there was a great debate over the actual *use* of notation: Some students wanted a record of their actions, while others only wanted a representation of the final amount of candies. It is significant to note that the rationales used in these discussions were often rooted in the students' imagery of the candy factory. Further, the quality of the students' reasonings illustrated both their growing understandings of the inherent conventions of standard notation, and their increasingly sophisticated conceptions of place value.

The present data analysis suggests that although there was a wide variety of different interpretations by the end of the teaching experiment, all students had successfully developed more flexible conceptions of place value. There is a strong likelihood that this occurred because of the teacher's attempts to fold back the discussions to the imagery of the Candy Factory and the students' use of the *MacCandy Factory* in order to situate their informal activities. It appears that this alternative approach to software design combined with the teacher's expertise provided a way of building on students' informal strategies from the bottom-up to support their more formal mathematical conceptions of place value numeration.

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Multiplayer Activities that Develop Mathematical Coordination

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Abstract

Four computer applications are presented that encourage students to develop "mathematical coordination" — the ability to manipulate numerical variables in cooperation with other students so as to achieve a definite goal. The programs enable a form of computer-supported cooperative learning (CSCL). In this paper we describe the rationale and design of the programs, the results of an informal evaluation, and possible future work. The games were developed using a special software and hardware environment that facilitates the rapid prototyping of computer-based cooperative-learning materials. This research is part of an ongoing project entitled "Mathematics Experiences Through Image Processing" whose objective is to develop and test educational materials that introduce K-12 students to mathematical ideas within the context of digital image processing activities.

Keywords — Co-present CSCW, computer supported collaborative learning, mathematics education, mathematical coordination, multiple mice, color matching, curve fitting, chord matching, cooperative learning.

1. Introduction

This paper presents four activities that enable co-present or face-to-face collaborative learning. Computer Supported Collaborative Learning (CSCL) as a whole is designed to encourage cooperation, discussion of ideas, resolution of cognitive conflicts, and promote problem solving and higher-order thinking skills. CSCL programs can be divided into two types: those supporting cooperation at a distance and those supporting cooperation in a co-present setting. As video teleconferencing technology improves and gets cheaper, this dichotomy will become less clear. For now, however, cooperation at a distance is hampered by the low degree of apparent presence available and the lack of actual contact with other students. Co-present collaboration, on the other hand, allows students to interact directly, see each other's expressions and gestures, therefore communicate more effectively.

For large co-present groups (e.g., a classroom full of students), collaborative applications may run on a set of computers interconnected in a local area network. Alternatively, one or more computers may support the users in a "meeting room" configuration. Occasionally one computer is used by a small group of students sharing it simultaneously. While sharing of a single computer may present some logistical problems to the students, the necessity of sharing can promote communication amongst the students. Physically separating students to work individually on computers tends to discourage communication.

The programs presented in this paper were specifically designed to be used in this last situation, that is, by groups of 2-4 students sitting at one machine. The software and hardware allow all the students in the group to interact with the computer simultaneously, via multiple mice and a shared screen. Simultaneous input tends to reduce the conflict over access to the computer, and it may increase the average rate of learning for the students in the group.

The reasons to support cooperative learning has been well stated by Davidson [4] in relation to mathematics. Group learning addresses some of the problems associated with the isolative nature of typical mathematics curricula. As a whole, students working in a group become less discouraged and frustrated than students working alone. The group not only is a source for additional help, but it becomes a support network for members. Combining computers with group learning is an attractive possibility for mathematics education, because computers can empower students to construct and explore mathematical objects and worlds.

The programs we present are intended to support mathematics teaching with the 1989 standards by the National Council of Teachers of Mathematics. Numerous reports have documented the difficulties that K-12 students in the United States have with mathematics (e.g., see [14]). When pressed for a reason, students often complain that mathematics is "difficult" and that they don't see much use for it beyond simple arithmetic. In response to these concerns, the NCTM developed *Curriculum and Evaluation Standards for School Mathematics*; this document specifies not only the content to be covered but the many ways in which this knowledge should be brought to life and connected to other subjects. These ways include communication about mathematics, problem solving and posing, and integrating the teaching of mathematics with other subjects.

The goal of the *Mathematics Experiences Through Image Processing (METIP)* project is to use digital image processing and collaboration to help meet the NCTM objectives. METIP software and activities allow students to manipulate and view digitized images as objects which are simultaneously visual and mathematical. Students may work assigned problems or explore and make their own discoveries. Teachers may lead discussions about ideas such as image transformations, invertibility of functions, and effects of arithmetic operations on images that crop up during the computer-based activities.

We have created an environment that facilitates the rapid development of METIP programs. The METIP environment system software is designed in two parts, one which includes image processing primitives and the other, known as the *MultiIn* module, which supports either single-user or co-present CSCL graphical user interfaces. In particular, MultiIn is designed to support a multiplicity of input pointing devices with their tracking cursors all displayed on a single screen. With this system, small groups of students are able to sit at one computer and discuss activities as they are engaged in them.

The next section will discuss the previous work which lead to the decision to support co-present CSCL. In Section 3, we describe four co-present collaborative applications followed by the implementation considerations in Section 5. Section 4 details the preliminary results of our user testing. Finally, Section 6 will include some directions for future work.

2. Previous Work

A number of educational researchers have sought to exploit computer technology in promoting learning through collaboration. For example, Clements used the Logo programming environment in a collaborative setting (i.e. multiple users on a single input machine) to study student learning through cognitive conflict and subsequent resolution [3]. The results of their study suggests that the collaborative use of Logo encourages interaction, discussions, coordination of different ideas and higher order thinking [12]. Unfortunately, the use of the computer in this way also promoted social conflict over the input devices.

TurtleGraph [10] is a similar problem solving environment in which Lisp is used to command the cursor. Additionally the environment has the capability to allow communication between students. The system regulates the communication through button presses and an area for conversational dialog. The restricted communication is designed to make the communication between users more productive.

This type of interaction has been seen in many other distributed CSCL applications [2,11,15,16,17]. Synchronous networked collaboration can be enhanced by adding real time video conferencing, similar to cooperative work systems such as EuroParc's RAVE [8], or Clearboard [9]. Still, because the hardware inhibits direct visual access to partners, these systems do not foster the same level of communication as one finds in face-to-face situations.

Meeting room systems [6, 17, 18, 19] are specifically designed to allow multiple users, each on their own machines, to work collaboratively and still maintain direct face-to-face communication. Some of these systems include special table top monitors that do not obstruct views and/or one large main monitor which is shared by all and serves as a mechanism to synchronize views.

While these systems do encourage communication more than their distributed counterparts do, they do not evoke the excitement and degree of interaction shown by users of co-present video games. Of course, such games are designed to maximize the players excitement and suspense. However it may also be due, to some extent, to limitations of the underlying hardware, such as delays due to network bandwidth, or perhaps it is because the users of such systems are not focusing on exactly the same view of the given problem. Even in systems with a large shared view screen must constantly their attention from their own monitor to the front of the room to gain context.

MMM [1] is a multi-user system in which each person has control of his or her own mouse, but all are working on one screen. This is the same situation found in most interactive home video games developed by Nintendo, Sega and Atari. Ultimately, we would like to channel the excitement and interaction found in video games into an educational context while changing the competition inherent in most games into collaboration.

3. Applications

3.1. Design Goals

We have currently developed four co-present CSCL applications designed to promote strong cooperation between users on a specific activity. Therefore each activity has one definite, predefined goal, and each user must contribute equally towards reaching that goal. In order to successfully complete the task, the users must be able to communicate about the operations on the screen as well as the goal itself. In many cases the users develop their own "language" about the activity.

3.2. The Color Matcher

The Color Matcher is the CSCL application that we developed first. This activity was designed to promote learning and discussion about the RGB additive system used by most monitors for displaying color [7]. It won an industry award for its creative use of the Access.Bus multiple input technology.

The Color Matcher activity gives each of three players access to his or her own mouse which corresponds to a red, green or blue colored cursor on the screen. The goal is for the players to match a target color generated by the computer.

Figure 1 shows the Color Matcher user interface. The interface contains two color frames, the left is the target color and the one on the right is the users' color frame. The users' color is determined by combining the RGB values controlled by three horizontal scroll bars. The color values, which range from 0-255 depending on the position of the slider, are shown above the scroll bars. A scroll bar can be modified only by the cursor of the same color.

Although each user is only in control of his or her own color, the users are collaborating to reach the single goal of matching one color. In order to succeed at this activity, users must, at a minimum, communicate about the relative amounts of color needed. Users also need to communicate when they think they are close enough to check their answer.

Each color matching activity is timed to keep the students on task. Users are allowed at most 60 seconds to adjust the RGB values for each given color, although they may check sooner by clicking a button. Each response is given a score between 0 and 1000, where better scores are indicated by higher values. Scores are determined by the formula $score = max\_distance - dist / max\_distance * 1000$ where *dist* is the distance between the target and users' RGB values, as determined by the position of the scroll bar, and *max_distance* is the maximum distance possible in the color space. The entire activity consists of matching ten colors. All scores are recorded in a ASCII log file.

3.3. The Chord Matcher

The Chord Matcher application is very similar to the Color Matcher, except that the users are charged with matching musical chords rather than RGB colors. The chords vary from a relatively easy major chord, to more difficult selections of three random notes of a 5-octave chromatic scale. Each user selects his or her note from the five octave range using a color coded scroll bar. As with the Color Matcher, users can only operate scroll bars of the same color as their mouse cursor.

Each user may hear his or her own note at will by clicking on a button. Similarly any user may audition the current team chord, or the target chord. Any user may also request a hint, up to a maximum of ten hints per session. The users are given 120 seconds to correctly match the chord, although they may check sooner. The team's score is calculated as $\lfloor 100 - 0.5 * (dist\_1 + dist\_2 + dist\_3) \rfloor$ where $dist\_i$ is the distance each users note was from the target note, measured in half steps.

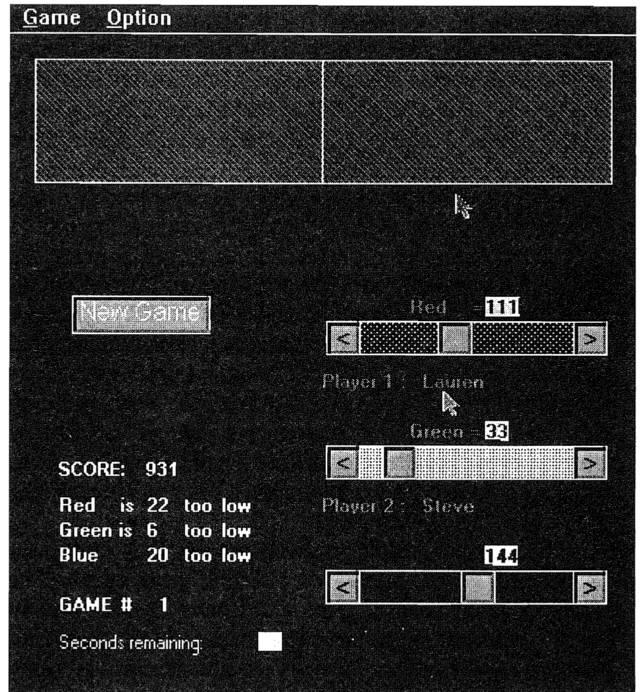

Figure 1. The Color Matcher User Interface.

The user interface for the Chord Matcher is shown in Figure 2. As with the Color Matcher, effective play requires that students talk about the pitches in the chord and when to check their answer. Additionally users may negotiate over the use of shared resources, such the use of hints, and when the notes, team and target chords should be played.

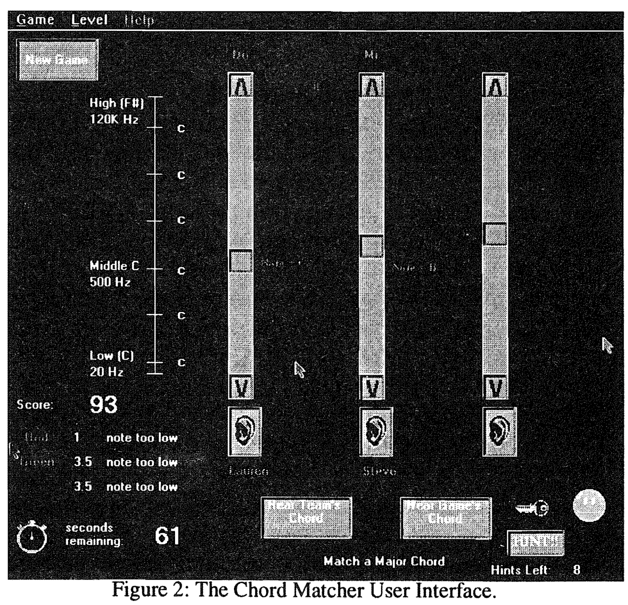

Figure 2: The Chord Matcher User Interface.

3.4. The Curve Fitter

The Curve Fitter activity is designed to allow students to explore how changing the location of control points modifies the shape of a polynomial curve. The user interface for the Curve Fitter is shown in Figure 3. This activity is designed for two to four users.

As with the Color Matcher and the Chord Matcher, each player controls a mouse which corresponds to a colored cursor on the screen. Each cursor can move a correspondingly colored control point on an image to modify the shape of the curve. The goal of the activity is to match a degree 1 to degree 5 polynomial with a curve in the image under 120 seconds. The users choose the degree of the polynomial before starting the activity. The scores range from 0 to 100 and is based on how close the curve is to the shape of the image. A high score is given for a close fit to the curve, thus a score of 100 represents the best fit of the curve.

Again the users need to communicate about the task they are performing. They typically discuss the shape of curve in relation to the locations of each of the control points. The only shared resource in this game is the button to check their answer.

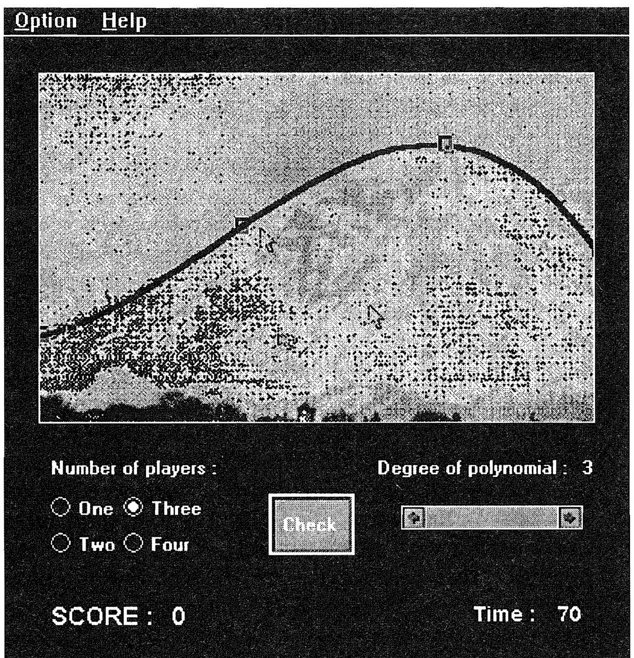

Figure 3. The Curve Fitter User Interface.

3.5. The Midpoint Activity

The Midpoint Activity is designed to encourage communication about certain geometrical concepts. The activity may be played in a two-person or three-person mode. Each user is in charge of the colored point matching his or her mouse cursor. If two users are active, they are charged with matching the midpoint of the line defined by their points with a predefined point

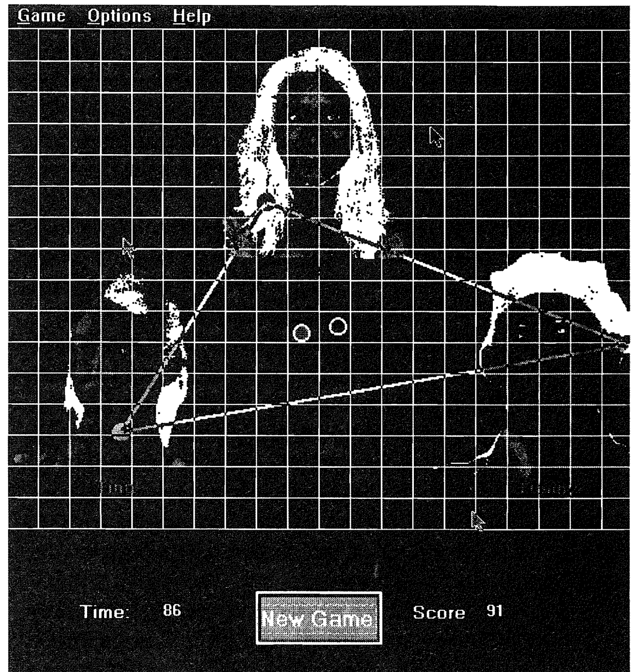

Figure 4. The Midpoint Activity User Interface.

on the screen. When there are three users engaged in this activity, they must match the centroid of the triangle defined by their points with the specified point. But there's a catch - the movement of each of the users' points is limited to areas on the screen defined by bitmapped images.

The users of the Midpoint Activity are given two minutes to complete their task. Since they can only move their own points, they must work together to match the target point. Again, the only shared screen resource is the button where the users can check their answer. The number of users and bitmapped images may be selected before each session.

Scores for the midpoint activity are determined by *100 - (dist * factor)* where *dist* is the distance between the users' point and the target point, and *factor* is a predefined value. Figure 4 shows the user interface for this activity.

4. Preliminary User Feedback

4.1. Testing in 8th grade classes

We tested the Color Matcher in two 8th grade mathematics classes in a Seattle middle school. Our goal was not to conduct a scientific experiment, but rather to collect anecdotal evidence to support the use of the cooperative facilities provided by the MultiIn module.

The students were given a lecture of about 15 minutes about the RGB additive color system. The lecture was followed by a short pretest and questionnaire. The pretest was to assess their understanding of the concepts presented in the lecture and to access how much they might want to pursue further investigations of color.

We divided the classes into groups of six and brought each group to the PC lab. Three of each group used the *Multiple input device (MID)* Color Matcher described in Section 3.2. The other students used a *Single Input Device (SID)* version of the same software. The students were shown how to use the software, then left to do the activity by themselves. Student interactions were videotaped for later study. Finally the students completed a post-test to determine if their knowledge of the RGB color system had increased. Students were also had the opportunity to give their impressions of the program in the follow up questionnaire and on videotape.

The majority of the students responded that they had seen color mixing before, though it is uncertain if they meant the RGB (additive) or CMYK (subtractive) system typically taught in grade schools. However, as a whole they had not previously used a computer to experiment with these concepts. The SID users were quiet, except to ask questions on how to operate the software. In contrast, the students using the MID software communicated a great deal, commanding each other to add "more green" or "less blue." Unlike the cooperative Logo studies done by Clements [3], there was very little conflict between these users as there was no contention for the input resources although some students did get slightly frustrated in discovering that they could not manipulate another player's color.

Overall the students enjoyed playing with both versions of the software. Some of the students restarted the activity after they had completed the test. One even used it to help answer the questionnaire. Another commented: "Having a computer at home you get used to working by yourself. But working together was more fun." Though another did say: "One player is better because its easier to get the right answer. You don't have to worry about what the other people are doing."

There was one group in particular that was very quiet and quite obviously did not get along very well. Their comments were mostly negative, though apparently aimed primarily at the teacher and at mathematics in general rather than the color matcher.

Scores on the test portion of the data are shown in Table 1. The students showed an increase in scores after using the color matcher, and there was slightly more of an increase among students that used the MID version of the software.

Table 1. Average scores on the pre- and post-test. Numbers in parentheses indicate sample size and *s* is the standard deviation.

	Single (7)	Multiple (15)
Pretest	2.33 s=1.66	4.13 s=2.80
Post-test	3.00 s=2.00	5.33 s=3.64
Change	28.76%	29.06%

4.2. Testing with college and graduate students

All of the collaborative applications were tested at the University of Washington. The volunteer testers, both graduate and undergraduate students most of whom had never seen this type of interface before, were selected in groups of three. Each group used each of the four applications, then answered a questionnaire in which they were asked to write down their impressions of the software and the interfaces. Additionally the group interactions were noted by three observers during the testing. No pre and post testing of knowledge was done.

In general, the users thought the interfaces were interesting and easy to use. Although all of the users gave some suggestions for improvement, none of the suggestions radically modified the underlying design for collaboration.

The students liked using the activities with partners, although they admitted they would rather use them by alone. (Perhaps this is due to the fact that they have all been taught to work and learn independently.) They did feel that the user interface made them communicate. One person noted, "[the interface] forced me to give or receive instructions." In fact, there seemed to be one person for each application who took the leading role in both explaining the underlying concepts of the activity and directing others. This type of tutor-learner relationship occurred most often during the testing of the Color Matcher and the Chord Matcher. In the case of the Color Matcher, there were a few people who didn't understand the RGB mixing scheme. This was even more evident in the Chord Matcher testing. In each group there was at least one person who was more versed in music theory than the rest. Between the tutors and the help screens, the groups decided that the best way to solve the easy (major) chord was to match the low note, then determine the middle and high notes by simply adding the proper amount of half-note steps. One person, who had perfect pitch and was able to match notes almost instantaneously, said "it's not fair for me to do this [activity]."

Unfortunately the users also pointed out that the Chord Matcher is inherently less collaborative than the others. One person's strategy was to "work on my own note individually, [then] offer suggestions to others after I'm done." The Color Matcher had the same problem, although the goal for the group is more tightly coupled than the Chord Matcher. In the former, the color homogeneously mix to form one, while in the latter the three notes are distinguishable by some people. Ultimately the team goal in the Color Matcher is the final color, whereas the goal for the Chord Matcher is to match the individual notes. In both of these applications, however, most users did not change their scroll bars while others were moving, presumably to see the effects of each scroll bar individually. One user commented they "picked something and let everyone else fight for a while, then made corrections."

The shared controls forced the users to communicate in a slightly different way. Typically a user asked the others in a group if he/she should or could use a shared control. In two distinct cases, users pressed a button without first asking for a consensus from the group, but did so only once. They realized afterwards that it was a shared resource and therefore its use should be based on a shared decision.

Finally, the users indicated that they did not feel hindered by the fact that they could only manipulate their own controls. In fact in the Curve Fitter and Midpoint activities, they felt that this forced them to communicate more. As one so aptly put it "You are forced to talk if you want to 'win' the game since you only control one piece of the puzzle."

5. Implementation Considerations

The four applications discussed in Section 3 were specifically designed as co-present CSCL activities for groups of 2-4 students sitting at one machine. The small group size was not only chosen to facilitate easy access to the machine, but also because groups of this size seem to work best for collaborative learning [5]. Furthermore, working in small collaborative groups teaches students skills needed in later life to interact with their peers in college or on the job.

The goals of these activities, as directed by the NCTM standards, are to favor conceptual learning over rote operations, emphasize practical uses of mathematics, encourage group discussions, and promote exploratory, open-ended discovery [13]. In particular, the programs described have relatively few shared screen objects (such as the check button). This forces the students to communicate with each other about manipulating the individual objects, rather than moving them themselves. In this way they are encouraged to share responsibility for the results of the activity. The use of multiple input devices for these activities not only avoids conflicts over hardware, but also has the added benefit that fewer machines are needed per classroom. The METIP/MultiIn environment has been developed on a 386/486/Pentium based PC platform running under Microsoft Windows because these systems are fairly prevalent in school systems. However, these stock machines only support standard single mouse/single keyboard hardware and operating systems. Therefore, we had to build support for simultaneous input from multiple students.

Video game joysticks are the most commonly used multiple user input devices. They have the advantage that they have wide support and can be plugged into a PC's standard game port. Unfortunately, joysticks are generally limited to two per machine and are difficult to use to control precise movement on screen. Using the keyboard to control cursor input has similar problems. While the keyboard is not expressly limited to one or even two users, it would be difficult to reasonably fit more than two people on any one keyboard at a time. The sole support of either of these types of controls would severely limit the range of activities MultiIn could support.

With the ability for relatively fine control of cursor movement, mice have been the standard graphical controllers for Windows based applications. Until recently there was no support for this type of multiple mouse interaction on one PC system. The ACCESS.bus "locator" communication protocol is designed to allow multiple input devices to operate on a single machine. However, the ACCESS.bus protocol requires a special board and therefore our activities cannot be used on a "vanilla" machine.

These types of devices are only a small subset of what is available. Given the plethora of multiple input solutions, we chose to design the MultiIn system to allow applications to treat all of these devices identically. Additionally, this design does not force the application developer commit to one particular type of hardware device.

Our technique for interacting with any input devices consists primarily of mapping specific device messages into our own standard format to eliminate variability. All that is required to integrate a device into the MultiIn system is a new module which specifies the translations from the device's messages into our own messages.

6. Conclusions and Future Work

To explore the potential for co-presence (not distance or teleconferencing-oriented) collaborative learning with computers, we have focused on activities in which several students simultaneously interact on a single screen. We have presented four co-present collaborative applications, the Color Matcher, the Chord Matcher, the Curve Fitter, and the Midpoint program. Each of these activities is designed to encourage exploration and discussion about the activity through interaction with the computer, as well as interaction with other students through verbal communication, gestures and body language. Through such natural, non-computer-mediated communication, students can utilize the language as well as the concepts of mathematics.

While not complete, the preliminary testing provides anecdotal evidence the hypothesis that students do tend to communicate effectively about the problem when using co-present multiple input applications. There was also, as anticipated, no contention for input resources. Further testing needs to be done to determine the effects of changing or restricting the ownership of objects on contention for resources, conflicts among users, communication and learning.

These activities have been built on a framework designed to allow the rapid development of input-device independent CSCL activities. This framework helps to hide one of the major stumbling blocks to the development of co-presence collaborative applications: the lack of standardization of multi-user input hardware.

The design of our multiple-user multiple-input interface is as yet incomplete. We are currently considering what types of user features are require to support collaborative learning interface applications and activities. With this knowledge we will extend MultiIn to include high level primitives for collaboratively manipulating objects. The primitives in this new system will support both co-present and distance cooperation. Thus this system will allow us to test the differences between these two forms collaboration.

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Computer Partner in the Classroom: Fostering Small Group Problem Solving

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Abstract

Designers of an anchored instruction approach to learning envision a cooperative learning environment where students can create a community of inquiry while solving complex problems. This approach "anchors" instruction in the context of meaningful problem solving environments, engaging both teachers and students in sustained exploration of a rich problem space [3]. Anchored instruction requires reevaluating classroom structure, communication dynamics, and the instructional artifacts used in the process. A major challenge for anchored instruction, and problem based learning curricula in general, is to help ensure that each student learns while also gaining the experience of working collaboratively. One possible solution involves integrating the computer as an active "agent" involved in the instructional process. This paper outlines a theoretical framework to define a learning environment that establishes the computer as a simultaneous partner for the teacher and the students and presents a computer program that employs this framework for use with students in a collaborative environment.

Keywords — anchored instruction, computer mediated instruction, problem solving, science education, small group collaboration.

1. Introduction

Anchored instruction and other problem based learning theories offer a rich context in which to explore methods of building collaboration by restructuring the classroom and integrating computer technology into the classroom discourse. The Cognition and Technology Group at Vanderbilt (CTGV) has explored a number of ways to enhance the potential of each student participating in a collaborative learning environment. The essence of the approach has been to devise situations that help make students' thinking visible to themselves as well as to their peers and teachers. Efforts to achieve this goal have lead to increased achievement and attitude gains [3].

2. Establishing a Partnership with Computers

Many researchers refer to computers as "cognitive tools" capable of amplifying or modifying cognitive ability. Salomon, Perkins and Globerson refer to cognitive effects as "effects *with* technology obtained during intellectual partnership with it, and effects *of* it in terms of the transferable cognitive residue that this partnership leaves behind in the form of better mastery of skills and strategies." They compare this partnership metaphor to a human partnership which includes: "(a) a complementary division of labor that (b) becomes interdependent and that (c) develops over time." [10]. How then does a partnership between an individual and technology manifest itself in relation to what goes on in a classroom? To answer this let us expand on these partnerships at the local level of computer/individual interaction, then discuss how to expand the partnership model to express the simultaneous dual partnership computer technology maintains with students and teachers in a classroom setting.

The first partnership between individual and technology, a systems view [7,9], includes the cognitive effects *with* the technology. The systems view teams the individual with the technology to form a joint intelligence which shares the labor during the cognitive process. This type of cognitive distribution manifests itself in two forms. First, the technology can serve as an amplification of an individual's own ability. Consider how a mechanical lever can amplify physical strength to move large objects; the lever cannot move the object without human intervention and the human cannot move it without the lever. An analogous technology/individual partnership includes an individual working with a spreadsheet on a computer. The individual can define the constraints of the problem and control the creative process as the computer performs the massive computations, permitting investigation of alternative solutions. The cognitive effect with this technology results in an amplification of the cognitive ability of the individual.

In the second partnership between computer and individual, an individual view, the computer functions as a method of scaffolding an individual's cognitive abilities. We assume that individuals have limited cognitive resources available for processing new information based on their previous experience and sensory input capability. The computer, with its self pacing, wide symbol system of representation, can provide a mechanism for organizing or presenting information so that the individual is affected by the interaction [5]. The computer can model how it finds information to instruct the user in the aspect of the task, or "off load" part of the cognitive process, allowing the user to focus cognitive resources elsewhere [6]. In principle, over time the user will develop the cognitive skills necessary to accomplish many of the cognitive processes demonstrated in the partnership.

3. Dual Role of the Computer

The traditional model of one teacher to many students is constrained by classroom size, structure and traditional instructional artifacts. A teacher must gear the classroom discussion to the mean ability level of the class to reach the largest number of students. Less competent students cannot fully participate and extremely skilled students may become bored. However, if we expand the partnership idea to include the simultaneous dual role of the computer, then a new definition of the classroom environment results in the computer closely integrated with the instructional process. Figure 1 illustrates how the "agents" in this learning environment work with each other to accomplish the activity of teaching and learning.

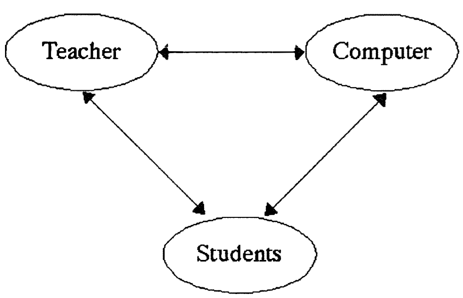

Figure 1. Teacher/Student/Computer triad.

The teacher/computer partnership utilizes the systems approach to introduce new concepts to students. The expressive power of the computer amplifies the teachers ability to instruct the class on a given domain topic. When students work in small groups, the instructional burden of mediating group dynamics is shared by the teacher and the computer. In this setting, students can receive some assistance to continue with their activity while the teacher assists other groups. The computer functions as an intelligent assistant that "understands" the instructional goals of the teacher and can provide feedback to the teacher. Feedback can be either synchronous with a small group activity or after the classroom meeting time in the form of a performance report. The end result is an instructional environment in which each computer assists the teacher in classroom activities with a common goal of instructing students.

The computer/student partnership can manifest itself from both perspectives. Traditionally, the "individual view" of students receiving assistance from the computer during drill and practice exercises, or even intelligent tutoring sessions, outside the class meeting time offers a disjointed presentation of information from the classroom presentation. In the dual model, the potential for deeper understanding may increase because of the strengths of sustained exploration of a given problem space and the benefits of shared expertise during whole class and small group discussions [8].

4. Inquiry in the Classroom

The dual partnership model of the classroom can be demonstrated by combining anchored instruction with computer mediated instruction. This section discusses the similarities and distinctions between two programs that combine anchored instruction and computer mediated instruction, the Computer Supported Intentional Learning Environment (CSILE) and a workstation environment, called QUEST, designed for use with small groups.

4.1. Anchored Instruction

Anchored instruction [3] provides a rich macro-context in which students and teachers explore possible solutions to problems. The problems may be posed through a variety of media; however, a video based format has proven to be a highly effective method of presentation [3]. The computer can easily be integrated into this "dialog" by assisting with the initial presentation of the problem and assisting the teacher in orchestrating the whole class or small group discussion. The computer can mediate the inquiry process by providing a set of tools to assist the group in understanding and solving the problem.

4.2. Whole Class Discourse Management

Computer Supported Intentional Learning Environment (CSILE) provides a general purpose environment to facilitate a discussion between class members through a network of computers. Students work individually or in small groups to generate and comment on solutions to problems posed by the teacher or other students. The teacher can use this environment to assess students understanding and guide the discussion to a deeper level. One of the strengths of this environment is its ability to keep a running history of the discourse. Students are encouraged to reflect on their own thoughts as well as those of others in the community. The result is a collaborative environment where students use each other as a resource for information and the teacher acts as a facilitator who guides students to a deeper understanding of a particular topic related to an anchor[11].

4.3. Facilitation of Small Group Discourse

Another method of supporting inquiry during anchored instruction focuses on small group interaction. The computer provides a level of scaffolding beyond structuring the classroom discourse through keyword structures. Instead of students sharing information across a network of computers, the students work in small groups in a self contained computer environment. The interface provides an impetus for discussion between group members by providing a set of resources to explore and collect information while attempting to solve an anchor. The following presents a specific example of how this instruction might be situated.

4.3.1. Questioning Environment to Support Thinking (QUEST)

The problem is posed using a video called the "Golden Statuette" [4] that depicts a modern day version of the Archimedes story. In this version a boy attempts to sell a lead statue painted gold to a metals dealer. The students must solve the problem of how much to pay for the statuette. The program provides tools for comprehending the video-based problem and investigating properties of the statuette [2]. In this environment students can experiment to construct the knowledge they need to solve the problem.

Identifying a problem is the first part of solving a problem [1]. The primary source for exploring the problem is through the anchoring medium; therefore, as shown in Figure 2, the students have direct access to the video based story in the form of a Quick Time (QT) movie stored on a CD-ROM. The students may use the standard scrolling bar beneath the video to review it for important information. The tool below the scrolling bar allows the students to create a "marker" for a specific range of the movie. With this tool they can label and save important data in the movie and quickly retrieve it through the list of markers in their notebook. This notebook, on the right in Figure 2, functions as a central collection resource for all the information the students generate and find during the inquiry process. The first goal is to describe in the notebook what is happening and what potential problems exist.

Once the problem has been defined and possible goals for solving it discussed, the students work with a set of tools to begin exploring properties of the statuette. Figure 3 illustrates the array of tools organized to provide students with a way to simultaneously view all the components of the problem solving process. The global problem, or goal, is posed at the top of the screen. The virtual laboratory area beneath the problem provides the tools used to obtain physical proper-

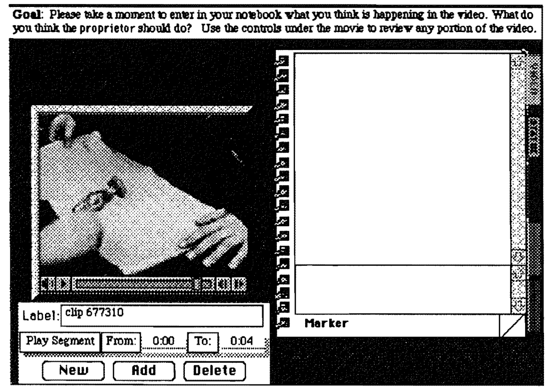

Figure 2. Problem posing/exploring screen.

ties of the statuette. As an example, Figure 3 shows the beaker tool with the statuette submersed. The process is fully animated to provide visual cues.

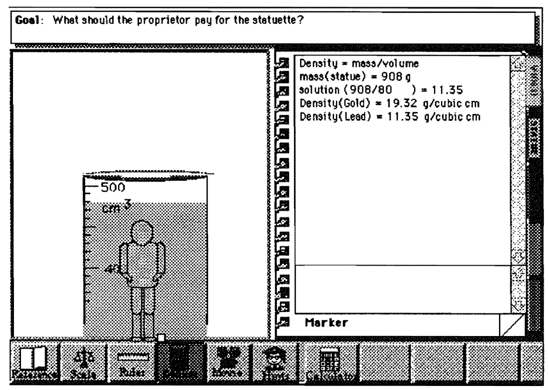

Figure 3. Beaker tool with statue submersed.

Other tools allow students to weigh and measure the dimensions of the statuette. Students can easily access a database of information including geometric relationships, physical properties of materials, price of materials and other scientific information using the reference tool. Students may browse through this information and copy any of its contents into their notebooks. A simple "click and drag" operation allows the students to move facts from the reference materials or measurement tools to the notebook. The electronic notebook provides a key feature to allow students to record what they feel is important, because they often forget to take notes. This feature helps students visualize the information they have mutually chosen as important. It also provides the teacher with a quick visual reference for where students are in the problem solving process. Therefore, the teacher can quickly assess and react to each group's individual needs. The collection and organization of these tools allows students to maintain a high level of exploration without being slowed down by collecting resource materials or recording information [6].

4.3.2. Hint Tool

The program allows students to ask for assistance as needed. The hint tool provides general assistance for using the tools and descriptions of basic science. More importantly the hint section presents a menu of "Things to think about..." questions that students might ask. Selecting one of these questions changes the focus from the statuette problem to a lesson that targets one of the important concepts needed to solve the problem. The students use the same set of tools to explore this new, more constrained goal posed in the lesson to gain insight into the applicable concept. Students can receive hints about the current problem, the statuette or lesson, each time they enter the hint section. These hints are scaffolded beginning with indirect questions to guide inquiry and progress to direct instruction. The design of this help section encourages students to assess their own thinking by deciding what type of help they need.

5. Pilot Testing

Initial pilot testing of the program revealed interesting qualitative results. A classroom of twenty-eight seventh grade students working in pairs attempted to solve the problem. With few exceptions, students expressed a preference for working collaboratively, generally in pairs. The level of dialogue between the students was very high, suggesting that the program will function well as a collaborative tool.

Students were motivated to solve the problem, as reflected by self reported measure called events that energize (ETE). Most students also indicated that they would like to work with similar tools in the future. The students' natural curiosity seemed to encourage them to explore all of the tools and to make use of the help section. Students indicated that they found the notebooks quite practical and effective for recording information. Preliminary analysis suggests that the environment may have a significant effect on post test results, especially on problems quite similar to that posed by the anchor.

6. Conclusion

In conclusion, designers of computer mediated instructional environments might consider this dual user function of the computer in a classroom setting. They should consider all the functionality a computer can provide not only to the immediate user of the technology, but also the other agents sharing the responsibility of instructing a whole class. Classroom environments using problem based learning methods like anchored instruction can benefit from computer technology that facilitates the collaboration between teacher and students and student to student. The end result is an environment that integrates the computer into classroom activities, increasing the potential for all students and the teacher to benefit from the partnership with the technology.

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Reframing Learning in CSCL Environments

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Abstract

The exploratory work presented here is part of a pilot study to identify users' communication and interaction needs when collaborating through on-line computer networking. The theoretical background is human action theory, situated learning and interactive learning process. Four groups of students were each exposed to two different collaborative tools. Preliminary findings show that such tools require an adaptation period, develop awareness and specific skills and can produce interesting learning and interaction outcomes.

Keywords — Human Action Theory - nteractive Learning Environments - Interface - Learner's actions and interactions - Actors - Meaningful and Social learning.

1. Introduction

Studies in collaborative learning (O'Malley, 1995) stress the need to " focus more on the processes involved in successful peer interaction, rather than just on learning outcomes ". With the functionalities afforded by new networked technologies, there is now the potential for students to share their learning experiences with each other and also interact more dynamically with their tutors. Although asynchronous computer supported collaboration has been a frequent research interest (Harasim, 1990), on-line synchronous work is an issue that has received very little attention in the area of CSCL. Because synchronous interactions are an essential part of academic training (Cf academic learning as second order experience of the world, Laurillard, 1993), we chose here to focus on synchronous tools, allowing for immediate active interaction and feedback between learners.

We are, therefore, particularly interested in whether technology-mediated synchronous communication and collaboration between students and tutors can facilitate the process of learning to learn. To this end, we consider the interface between networked co-learners to be a central issue. Our work focuses on determining the most appropriate way of distributing work and communication spaces such that collaborative learning, comprising both communication and working, can be seamlessly supported and co-ordinated.

2. Recontextualizing Learning from a Human Action Theory

Human action theory is an approach which provides theoretical tools for rethinking human cognition, its inherent complexity and its social and cultural dimensions. Overriding many of the shortcomings of information processing theory, the concepttual approach is based on the human being as a social, intentional, motivated and situated "human actor" with a personal history and a psycho-biological presence to the world. In the study of computer supported collaborative learning, this means taking into account the characteristics proper to a situated, psychological, social incarnated actor in studying his specific learning activity. In this approach the learner is seen as capable of transforming the objects at the same time that he transforms himself. In this perspective, cognitive objects and tasks only exist inasmuch as they are produced by a subject.

From a learner-centred and interaction point of view, learning activity is not a computation or manipulation of representations, learning is constructing meaning from information based on a human capacity to make sense and to share meanings with someone.We analyse real life learning situations and identify learning as a dynamic, multidimensional activity of intentional, motivated and self-organising actors rather than as "acquisition and modification of cognitive states and structures determined by an ordered set of functionalities and rational processes finalised by the causal necessities of a predifined task" (Linard,1993)

Human Action Theory shows us that cognition is a mental and psycho-biological action at the same time. Human Actors are social beings that need a meaningful context in order to planify goals and achieve them in an organisational perspective. What is at stake in learning is not only intelligence and knowledge construction but more basically self-identity and relating through interaction with other people. CSCL environments must provide for both dimensions if they are to have any significant integration in mass-education. Concerning Collaborative learning cannot be defined only as "extending instruction to off-site areas using communication technologies". CSCL brings into play other factors to pertaining human mediation through technology.

3. Context and Methods

The preliminary findings presented are drawn from empirical work carried out within a more comprehensive research on communicative interfaces for collaborative learning. Collaborative learning is not a new topic, but computer supported collaborative learning is. As the field is not sufficiently structured, we think it is necessary to produce exploratory findings, by setting up situations of use and observing, questioning and trying out different alternatives. We experimented with four different collaborative writing tools trying to assess the appropriate task framework and time span of observation to obtain the most significant results. The complete exploratory study is intended as a comparison between different collaborative writing tools, centred on the way students would move from one type of space to the other: shared vs private work spaces, and communication vs work spaces.

This exploratory work is designed to provide knowledge on learners' communication and interaction needs when collaborating through on-line computer networking. Because so few aspects of synchronous computer supported collaborative learning have been studied, we chose to work in real-life settings with motivated students personally interested in exploring these tools. Several studies were conducted comparing face to face collaboration with computer supported collaboration, or comparing uses of two different collaborative tools by the same group. Observations and analyses reported here are based on the use for synchronous collaborative learning of existing groupware by four groups of between two to five students. Each group was given a collaborative task and exposed to two different collaborative situations. Students were from different training programs: engineering, psychology and cognitive science. Two studies included interviewing participants before and after their task and others videorecording, taping conversations and recording the students' written communication and the resulting work.

Co-writing was chosen because it is based on one of the most popular uses of microcomputers, word processing, an application usually provided with all computers. Some of these tools have become standards, such as WordPerfect™ or MicroSoft Word™. This choice aimed at minimising the time span necessary to become familiar with the collaborative tool.

3.1. The tools

The tools used in the different studies had to provide basic functionalities for collaborative writing and editing and are :

- Reach Out™[1], a screen sharing tool for PC
- PictureTel LIVE PCs 100™[2], a desktop videoconferencing system for PC,
- ShrEdit™[3], an experimental CSCW prototype software, on Macintosh,
- Aspects™[4], a commercial CSCW software on Macintosh.

All tools allowed the setting up of a common workspace and a communication space. Two of the tools allow on-line writing and editing with each participant taking control alternatively over the shared document. The other two tools allow simultaneous writing and editing on a shared document. Tools selected had to be robust and compatible with the computers used in training, that is PCs or Macintosh.

3.2. Study Set-up

Different types of situations were observed such as:

- Students doing a collaborative task as an extra feature in a course which did not include computer use;
- Students working in a co-operation base group, doing a collaborative task as part of a curriculum which did not include collaborative tools,
- Students doing a collaborative task as part of a curriculum which included the use of collaborative tools.

4. Prelimirary Findings

Based on our preliminary analyses of the ongoing studies, we have established some findings that need

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1 Reach Out™ is a screen sharing tool allowing remote control, and is commercialised by Ocean Isle for PC.

2 PictureTel LIVE PCS 100™ is a videoconferencing system for PC allowing the interconnection over an ISDN network with one or more videoconferencing system.

3 ShrEdit™ is an experimental CSCW software allowing shared word- processing and drawing.

4 Aspects™ is a commercial computer supported collaborative software for co-writing and drawingdrawing on Mcintosh, and allowing the interconnection with up to sixteen other computers.

further investigation. They are summed up in the following five points:

(1) **Intention and goals**

The decision to use these tools, in what way and for what task, is very important in determining the way the tools are used. Therefore knowing the intentions and goals of the users and their understanding of collaboration, is necessary to assess the uses. In such a situation, which is neither regular nor familiar, intentions have to be made explicit in order for everyone to understand what is happening. Goals partially determine and structure the activity and the learning going on has be understood in the light of the goals pursued. The human activity framework provides essential guidelines to understand the processes.

(2) **Complexity of tools supporting synchronous collaborative learning**

Synchronous collaborative tools, at this stage of their development and implementation, are not easy to use. They are very complex tools and, because of the interface and the situation of collaboration, can easily overload the learners. Initially, it is difficult for them to make sense of the interface, from which to learn an appropriate model of themselves, the collaborative task, the computer tool and the group working together. Users need to develop a conceptual model of what the computer does actually, what it enhances. In order to collaborate in any meaningful way, therefore, the learners have to develop a rich understanding and synchronised view of what is happening in the computer-supported environment.

(3) **Skills for computer supported synchronous collaborative learning**

Collaborative learning involves collaborative skills. " The skills especially important for co-operation are communication skills, skills in building and maintaining trust, and controversy skills. " (Johnson & Johnson, 1975). Very often these skills are practised without explicit reference. Students are often unaware of what is required of them in a collaborative activity even when they are able to cope rather well with the situation.

Collaboration is not technologically based in our culture. In computer supported collaborative learning, participant need to identify the different social skills that are being activated Collaborative tools oblige to a greater awareness of what collaborating with someone means, what it involves. Some aspects are amplified by the technology and come to the forefront such as explicit cues necessary to become aware of the others' actions at a distance.

Synchronous computer supported collaboration is a very sensitive situation. Unawareness can be very costly in terms of what is lost in a collaboration if there is no landmarks to appreciate whether communication is taking place or not. Typing is not a spontaneous or easy way to communicate for most people, for it slows down the exchanges, obliges to a structuring of the information and provides little feedback. Videolinks can be misleading for these is no immediate feedback on what the other person is actually doing or looking at.

One finding is that when using collaborative tools, collaborative learning does not happen immediately. It is necessary for the co-learners to spend considerable time familiarising themselves with the tool and communicating with each other at a distance. In turn this requires developing a social protocol as to how to coordinate their activities before even any collaborative learning can take place. This implies that collaborative learning needs to take place over along period of time before any significant benefits can materialise

Furthermore, in one study, it was found that having developed an initial shared understanding of the learning environment and the task that had to be carried out jointly, the participants then had little difficulty in dividing their attention between the separate interface spaces for communication and work.

In the videoconferencing situation, students found that contrary to their expectations, they had great difficulty in getting the attention of the other party, and never knew if they had succeeded in doing so, mainly due to lack of eye contact in a videoconferencing setup. In another situation, limiting communication to typing in a chat box turned out to be experienced as more efficient, allowing for more reflexive and well prepared comments than in face to face or videoconferencing situations.

Another interesting finding was that the students could articulate for themselves what they had gained from the collaborative learning setting. Those who has communicated by typing were very interested in the log of their chat box. This contrasts with face-to-face settings where students find it more difficult to reflect on their learning and communication strategies. We suggest one reason for this difference is that computer-supported collaborative learning forces the students to be more explicit with each other of their intentions, goals, plans and current understanding of the task in order to collaboratively progress with the task.

(4) **Learning production or outcomes**

After a familiarisation period, students can expect specific gains when working with collaborative tools. Students developed, or felt the need to develop social protocols, so as to counterbalance the lack of usual social cues to communication and awareness of the other's reaction:

⇒ A more elaborated conception of collaboration, of each person participation;

⇒ Familiarity with the software tool;

⇒ Sharing more ideas,

⇒ Improved shared understanding,

⇒ Better quality output (essay, presentation, synthesis...).

(5) **Characteristics of target group users**
Collaborative computer-based tools select users: first of all, computer fluency is a must because of the synchronous type of work studied, the interaction between the users has to reach a minimum level of spontaneity; therefore collaborative writing tools can be easily integrated in a collaborative activity only by people already familiar with typing and fluent enough to rapidly produce or edit a text.

Users must also have time to experiment and train in order to develop fluency in the use of these tools. Time can be a very scarce resource with some groups. This is a real problem for studies such as these, for there is an important time span that has to be lived before the tools are integrated.

5. Conclusion

We are currently continuing with our detailed analyses to examine further how the structuring of the interface affects collaborative learning. At this stage, we propose to carry out further research in the following areas:

- the emergence of self-directed collaborative strategies - in particular how do the students themselves become aware of the benefits of collaborating via these computer systems and how does this subsequently improve their performance?

- the development of interpersonal, meta-cognitive and social skills - it appears that one of the main benefits of this kind of collaborative learning set-up is that student's mastery and awareness of such skills are increased.

- familiarisation and adaptation to the interface of collaborative learning tools - how do the students co-adapt to each other and the tool over a long period of working together and what are the longer term effects?

- identifying different communication channels and modes: how do students tailor their communication needs and activity in terms of the available channels and what are the basic functionalities needed?

Finally, besides pursuing our work on collaborative learning and communicative interfaces, we are interested in two complimentary projects dealing with fields that have received very little attention up to now: one is a study of synchronous interaction and asynchronous interaction in a pedagogical context in order to find out when each type of interaction is best suited to support the interactive critical construction of knowledge; the second is the study of interactivity for learning and the design issues and guidelines that could result.

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Simulating a Learning Companion in Reciprocal Tutoring Systems

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Abstract

This paper describes how student modeling plays a role in the implementation of a cooperative learning system, in particular, the simulation of a virtual learning companion. A scaffolding tool for solving Lisp recursive problems is used to support a protocol of cooperative learning, called reciprocal tutoring. During reciprocal tutoring, two agents, where an agent is either a real student or a virtual learning companion simulated by the computer, interact and take turns for playing the roles of a tutor and a tutee. We describe a method that takes the overlay approach of student modeling to simulate a learning companion. The method constructs the behavior of the companion, illustrating its advancing knowledge and mistakes. A preliminary evaluation of the system has been conducted.

Keywords — Collaborative composition, problem solving, multi-user simulation, cooperative learning, learning by teaching, learning companion, reciprocal tutoring, student modeling.

1. Introduction

As an alternative to one-on-one intelligent tutoring systems (ITSs), Chan and Baskin (1988, 1990) proposed a three-agent model, *learning companion systems*. They suggested that the computer can be simulated as two co-existing agents: a teacher and a learning companion. The learning companion is an artificial student who interacts with the student and learns under the guidance of the computer teacher. Thus, the learning companion performs the learning task at about the same level as the student, and both the student and the companion exchange ideas while being taught by the computer teacher. Integration-Kid, a learning companion system, explores various patterns of interactions through different protocols of learning activities of the agents (or the triad), such as, cooperation, competition, modeling, and observing (Chan, 1991). The performance of the learning companion in Integration-Kid is governed by a subset of problem solving expertise and some faulty knowledge. In the process of learning, this problem solving expertise is being expanded and the faulty knowledge is being tuned by simply deleting and adding knowledge units.

Social learning systems are emerging learning environments that involve multiple agents, working at the same computer or across connected machines. These agents are either computer simulated or real human beings, taking various roles via different protocols of learning activity (Chan et al., 1992; McManus and Aiken 1993; Jehng et al., 1994). These systems are sometimes called or closely related to collaborative, distributed, or distance learning systems. In some learning activities, the artificial learning companions together with the real students on the network can form a virtual learning group (Lai, 1994).

Of particular interest to this work is a protocol of learning activity where the student "learns how to learn by teaching the learning companion" (Chan and Baskin, 1988, p.199). This inverted model of ITS, which puts the student in the position of a tutor, instead of a tutee, is termed as *learning by teaching* and elaborated by Palethepu, Greer, and McCalla (1991) who describe a system architecture in a declarative domain represented by a semantic network. The system acts as an interactive knowledge acquisition tool and asks the student questions in order to complete the inheritance hierarchies. They speculate that such a system would be useful to a student who already 'almost knows' the domain and enhance the student's meta-cognitive reasoning skills. Following such a *tabular rasa* approach, Nichols (1994) develops a system. Subjects tested the system "express discomfort at having to feed a 'knowledge-hungry' agent."

Instead of using such *pure* co-learners, VanLehn, Ohlsson, and Nason (1994) suggested that a more complex system could use covert experts and pedagogical modules to move the dialogue in pedagogically useful direction. Besides being a learning partner of the student, a simulated student can potentially be useful for formative evaluation of instructional designer's prototypes and teacher training, thus the name 'meta-tutoring' (VanLehn, Ohlsson, and Nason, 1994; VanLehn, 1993). Ur and VanLehn (1994) apply explanation-based machine learning method to simulate a physics student for the purpose of tutor training and use it to study the cognitive process of learning from a tutor.

To emphasize individualization, student modeling is usually at the core of the research of ITSs. However, there are some objections of using detailed student model because of the practical difficulty in building it. Besides, since students may have different prior knowledge, learning experience, particular interests, social background, motivation, or personality characteristics, if all were represented in the student model, it may embrace almost all the problems in cognitive science. For more discussion of the arguments and counter-arguments of using student model, see Self (1988) and McCalla (1990).

There has been hesitation of using student models in social learning environments. For example, Palethepu, Greer, and McCalla (1991) found that student modeling seemed to be less useful and put it as an interesting open question whether student modeling is critical in learning by teaching. Also, Newman (1989) views learning interaction in a social context as a successive exchange of interpretations of the actions on the tasks by different agents. An agent does not have, or apparently need, an understanding of exactly how other agents approaching the task. Quite the contrary, it is necessarily somewhat ignorant of each other's mental state. All an agent has to do is to produce some moves that in some way contribute (or can be understood as an attempt to contribute) to the task. The other agents do not have to know exactly what the agent thinks he or she is doing as long as the other agents can regard that what the agent does contributes a part to the joint accomplishment of the task. The primary requirement of an agent's utterance is whether it makes sense to the other agents. By a sense making response, it means that the response possesses some relation with the past interaction experience that represents a range of expectations as well as the specificity of the current problem context. Therefore, if one's response is unexpected to others, others can express their unexpectancy explicitly.

This paper discusses how to use student model to construct a cooperative learning environment and to simulate a virtual learning companion for practicing Lisp recursion. The rest of this paper is organized as follows: Following a description of the design of the reciprocal tutoring system, we deliberate the system implementation, in particular, the modeling of a learning companion. After that is a preliminary evaluation of the system, and finally, a discussion.

2. The System

Cooperative learning is a form of learning activity to lessen cognitive load by partitioning the learning task into sub-tasks undertaken by different agents. Each agent is only responsible for a sub-task while the rest is being taken care by other agents. In the domain of learning to write programs, students have to understand the problem first, then formulate the problem in the conceptual model supported by the programming language. Followed from that are the code generation and debugging where the student iteratively generates and tests code. If there is an error, the student diagnoses the code, looks for a way to fix the error, receives advice if available, then revises the code. Code generation and debugging, being decoupled programming sub-processes, can be taken on by a tutee and a tutor respectively. In general, this view suggests that tutoring in problem solving in an ITS is a cooperative process between the student and the computer, undertaking two sub-tasks: tuteeing (learning by being tutored) and tutoring, respectively. If two agents perform these two sub-tasks alternatively, then we shall obtain a protocol of cooperative learning activity called reciprocal tutoring (cf. Palincsar & Brown, 1984). Having a student play the role of a tutor (or a critic) is perhaps inevitable for cooperative learning in problem solving domains, since problem solving usually requires feedback in solution development, unless there is a human or computer tutor. Furthermore, the conceptualization of reciprocal tutoring, we believe, offers broad applicability to other knowledge domains.

Learning in the Reciprocal Tutoring System (RTS), a student plays the role of a 'tutee' whilst the computer assumes the role of a 'tutor' and they take turns for different problems. When the student plays the role of tutee, the system is a typical ITS. A student model is kept inside the system to provide hints and feedback. The student uses a nicely designed scaffolding tool (see Figure 1) which is originally a part of the Petal system (Bhuiyan, Greer, and McCalla, 1992). Following the 'calculator metaphor', this Petal-like scaffolding tool (PLS) provides a set of Lisp 'code chunks' (or Lisp expression templates) displayed as buttons on the screen. These code chunks allow the student to construct code without making syntax errors. Thus the student does not worry about the legality of the expressions and can pay more attention to the semantics and the heuristic knowledge required for getting a solution. Also, the restriction of using single 'cond' construct (the 'cond' construct in Lisp is similar to the usual 'if' construct in most programming languages, but in a structured form rather than nested 'if') implies that this construct is by itself a schema that suffices to solve a set of recursive problems. For the system development, PLS provides two advantages. First, using the code chunk buttons instead of the keyboard, PLS cuts down dramatically the space of the student's possible responses. This permits the system to concentrate on expected responses, no matter whether they are correct or incorrect. Also, when the student is restricted to use a single 'cond' construct, the number of possible correct solutions diminishes to one or two solutions only. This, in turn, affects the design of internal student modeling when considering how to model the student and the learning companion.

The student tutor can see the correct answer and every action of the computer tutee, while playing the role of a tutor (see Figure 2). When the computer tutee is working on a problem, the student tutor, who knows the answer, is watching how the tutee works. However, knowing the answer is not enough; when the computer faces difficulties or makes errors, the student, who is not necessarily more capable than the computer, may not be able to offer help. A natural way to handle this situation is that the system provides an intelligent 'super-tutor' to help the student tutor tutor the computer. This super-tutor at least has to make sure that the student tutor knows where the tutee's trouble is and is able to offer relevant help. Instead of implementing an 'active' super-tutor agent, we take an alternative approach to satisfy these objectives. We develop an intelligent tool, called the Diagnosis-Tree (DT), to be used by the student tutor in the process of tutoring.

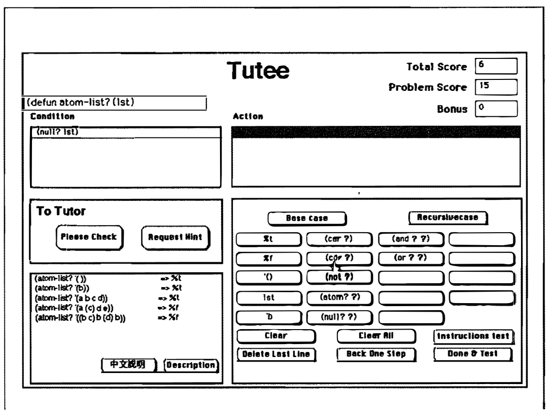

Figure 1. Tutee's Petal-Like Scaffolding Tool.

DT helps the student tutor identify where the error is and construe why it is an error When the computer tutee 'presses' the button of 'Request hint' to ask for help, the tutor does two things: locates the tutee's trouble and chooses a hint to give. The tutor expands the DT, starting from the 'base case' or 'recursive case' nodes (displayed as buttons on the screen). The tutor is required to pick up the correct path in expanding the DT in locating the error. First, the tutor has to judge whether the current clause is a base case or recursive case. The highlighted part in Figure 2 is the action part of a recursive clause. When the tutor presses the 'recursive case' button, the DT expands and displays three buttons - 'recursive case incomplete', 'recursive case incorrect', and 'correct'. If the tutor selects 'recursive case incorrect' button, the DT will further expand and generate two buttons - 'condition incorrect' and 'action incorrect'. Nodes will not expand if the tutor hits the wrong button. When the tutor has successfully spotted the student's trouble at the end of the diagnosis path expanded (in this case, the 'action incorrect' button), a number of hints in Chinese (can be easily anglicized, of course) are available (see Figure 3). These hints explain errors, suggest possible approaches or Lisp functions to be used, or offer answers directly. The tutor will pick a hint and send it to the tutee. If 'more hint' is requested by the tutee, the tutor will send another one. A point system is used to make sure that the dyad will not depend too much on the DT and will pay more attention to each other throughout the process. Points will be scored or deducted according to the performance of the tutor in locating the tutee's errors and there will be penalty of using hints that are too close to the answers.

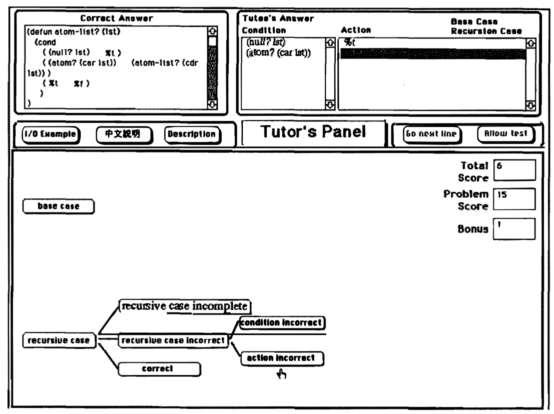

Figure 2. Student Tutor's Interface (I).

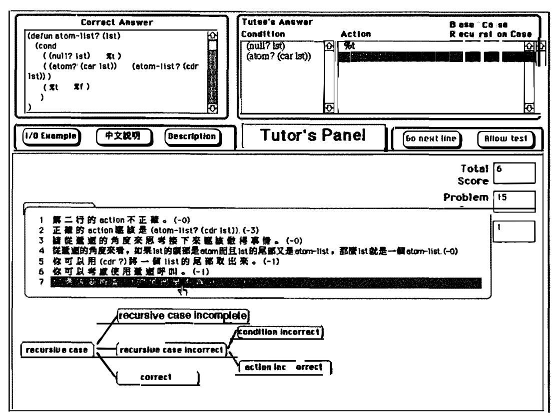

Figure 3. Student Tutor's Interface (II).

3. Simulating the Learning Companion

Reciprocal tutoring system is implemented with SuperCard and Lisp on MacQuadra and PowerMac, using AppleEvent to link the two application programs. A small Lisp interpreter written in Lisp is used for testing student's program and the student may use it to verify the properties of the Lisp language constructs.

3.1. Modeling Tutor

To simulate a tutor, like ITS, we implement a student model, and use that model to build the DT. We compare the student's solution with a discrimination net, a simple artificial intelligence technique, to keep track the student's actions. For each problem, based on the correct solution and the error data collected for this problem (in a separate experiment where students used PLS), we set up a discrimination net. Each node in the net represents a possible situation of the student's program and stores different levels of hints and suggestions. When the student requests hint, the student's program is matched with the net. On termination at a certain node, the current situation of the student's program is recognized and the associated hints are then available for the tutor to deliver. Using the schema (a single 'cond') constrained by PLS, the problem's latitude has been narrowed to one or two possible correct solutions, so the discrimination net is rather linear. The disadvantages of this approach is that each problem needs a discrimination net. The size of each net is rather large and is thus labor intensive to build. Nevertheless, this student model suffices to provide the computer the ability to point out the tutee's errors and supply hints about how and what to do next in solving a problem.

3.2. Modeling Tutee

To simulate a tutee, we have to model the behavior of a learner whose knowledge of the domain appears to be advancing, even making mistakes from time to time. The tutee's response may be incorrect. The tutee sometimes even may not be able to give a response and asks for help. Thus, two objectives have to be fulfilled: able to model the evolving knowledge of the tutee and be 'psychologically plausible' to the student tutor. By psychologically plausible, we mean that the learning behavior and performance of the tutee can be conceived by the student. Instead of applying machine learning methods to empower the learning ability of the tutee, we take an overlay approach to make the tutee pretend to learn at about the level of an average student.

We take an example to illustrate how the simulated tutee works. Let us consider the solution of a simple recursion that finds the length of a list:

```
(defun length (lst)
    (cond   ((null? lst)        0)
            (%t       (+ 1 (length (cdr lst))))))
```

If the tutee knows how to do this problem, then using the code chunk buttons on PLS interface, the tutee has only to construct '(null? lst)' and '0' for the first conditional clause and '%t' and '(+ 1 (length (cdr lst)))' for the second. For '(null? lst)', it is composed of two code chunks, '(null? ?)' and 'lst'. The tutee is able to use the code chunk '(null? ?)' means that the tutee understands the semantics of 'null?' (syntax has already been taken care by PLS) and knows that it is applied to the base case of this problem. So the use of '(null? ?)' in this problem is associated with two *concepts*: 'null?' and 'base-case'.

Now, we may assign a number from 0 to 1 for each concept to represent the tutee's proficiency of that concept. For example, if the tutee is very good at understanding 'null?', but not 'base-case', then we may assign the proficiency value of 'null?' to be 0.7 and that of 'base-case' to be 0.4. Knowing the proficiency value of the associated concepts of '(null? ?)', 'null?' and 'base-case', we take their minimum value, that is, 0.4, to be the proficiency value of the code chunk. So if a proficiency value of a code chunk is not high, it means that there is a deficiency of understanding this code chunk due to at least one of the associated concepts. Between 0 and 1, we may use four intervals to represent the grade of a code chunk: [0, 0.3), [0.3, 0.5), [0.5, 0.7), and [0.7, 1] for poor, fair, good, and excellent, respectively. Thus, the grade of '(null? ?)' is fair. Now suppose that the tutee is in the situation to use the code chunk '(null? ?)', then since the grade is fair, the tutee may ask the human tutor for hints. If the first hint is too general, then the tutee will ask for a second hint. If unfortunately, the second hint is related to the concept 'null?' that the tutee understand well, then the tutee will ask for another hint until there is a hint which is related to the concept 'base-case'.

For each problem, the simulation of the tutee will refer five components of the system: (i) a *tutee model*, (ii) a decomposed solution, (iii) the tutor's hints, (iv) the error code base, and (v) a set of response rules. The tutee model is a set of all the concepts of the domain and their proficiency values. The concepts range from simple such as 'null?' and 'car' to complex such as 'deep-recursion'. Thus the tutee model records the tutee's degree of understanding of the domain and hence its competence.

A decomposed solution is a list of code chunks decomposed from a solution of the problem. Each code chunk is associated with the required concepts. For example, a decomposed solution of the 'length' problem is [('(null? ?)'; 'null?', 'base-case'), ('lst'; 'null?-arg', 'atom'), ...]. Note that, these required concepts are context dependent, that is, different solution contexts may require different required concepts for the same code chunk. Also, there are no proficiency values of the concepts or the code chunks in the decomposed solution.

A tutor's hint, though in natural language form, can be analyzed to determine whether it indicates a concept of that code chunk. The error code base is formed by collecting mistakes such as the mixing up of 'car' and 'cdr', 'and' and 'or', '%t' and '%f', and error data from previous empirical experiments.

Response rules are heuristic rules that govern the responses of the tutee. There are four rules based on the computed grade of a code chunk and one for checking when the tutee finishes a condition clause:

If the grade of the code chunk is excellent, the tutee will display the correct code chunk.

If the grade of the code chunk is good, the tutee will display the correct code chunk, but the responding time is longer than when the grade is excellent.

If the grade is fair, there will be 25% possibility that the solution is correct and the responding time is longer than when the grade is good. The other 75% possibility is to respond with incorrect code chunk or ask for help.

If the grade is poor, the response is either showing incorrect code chunk or asking for help.

If the tutor completes a condition clause, the tutee will ask the tutor to check the clause.

At the beginning, the initial proficiency values of the concepts in the tutee model are taken by trial and error method through testing the behavior of the tutee to see whether they are reasonable for an average novice learner. Figure 4 depicts the data flow between different components in simulating the tutee and the algorithm works as follows:

(I) From the decomposed solution (a list of code chunks), get the next code chunk and compute the grade of this code chunk as follows: from the tutee model, retrieve the proficiency values of all the required concepts associated to that code chunk, get the minimum of these values and transform it as the grade of the code chunk. If there is no more code chunk to be tried in the decomposed solution (problem has done), terminate.

(II) Use the response rules to determine what the tutee would do. Four possible responses:

(IIa) Display the code chunk (correct response), then go to (I).

(IIb) Ask for help. Keep asking for hint until the hint indicates to use the required concept of lowest proficiency value of the current code chunk. Display the code chunk and update the proficiency value of that concept, say, add 0.05, in the tutee model, then go to (I).

(IIc) Make mistakes. Get an error datum from the error code base to display, then go to (I).

(IId) Ask tutor for checking. The tutor uses the DT to check. If the clause is correct, the tutor notifies the computer tutee to continue, then go to (I). Otherwise, the tutor points out the mistaken code chunk and then the tutee has to backtrack to it and re-try the whole clause, then go to (I).

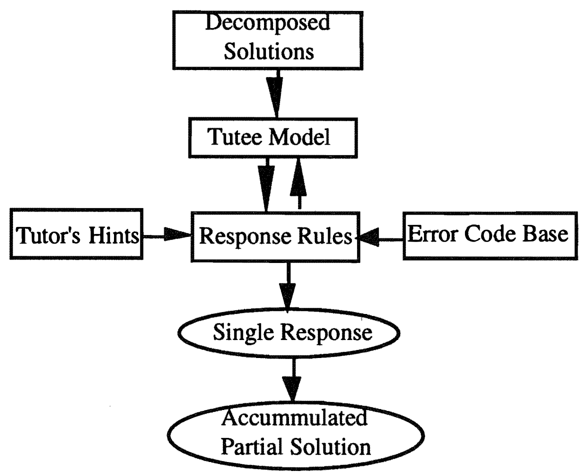

Figure 4. Data Flow Between Components in Simulating a Tutee.

Note that the consistently advancing competence of the tutee is due to the decoupling of the tutee model from the data (decomposed solutions and the error data base) to construct the responses. Moreover, this decoupling allows different problems to be independent to the tutee's behavior and thus new problems can be easily added into the system. Also, notice that the transferring of the proficiency knowledge from the student tutor's hints to the computer tutee is in a rather straight forward manner. Finally, if a problem has more than one solution, the system will choose one of the decomposed solutions for reference.

4. Preliminary Evaluation

As previous description, Reciprocal Tutoring System (RTS) enables the student and the computer to switch the roles of a tutor and a tutee, thus, if there is no role reversal, it essentially consists of two sub-systems:

Computer Tutoring system (CTS) and Human Tutoring system (HTS). With these two sub-systems, we can study the sub-tasks, tutoring and 'tuteeing' (working on the task with the help of a tutor), separately. Together with the PLS (no hints provided), we shall compare the learning effects on students when using RTS, CTS, HTS, and PLS in our evaluation.

Twenty two freshmen who learned basic Lisp concepts before used the systems to practice Lisp recursion problems for two hours. Their mid-term examination was taken as a pretest and students were distributed evenly in different systems according to their pretest result. Each system version has 5 or 6 subjects to use. Then all took a posttest with Lisp language interpreter. Table 1 is the average scores of the students and their standard derivations in the posttest.

Table 1. Posttest Scores After Using Different Systems.

Systems	RTS	CTS	HTS	PLS
aver. / std. der.	78 / 4.79	77 / 13.9	64 / 9.7	70 / 15.2

Given the limited number of subjects per system, the result of these preliminary trials are not significant and can only provide us a picture of how to draw hypotheses about reciprocal tutoring. All PLS students like the system and think that they can focus better without caring about the syntax and it is convenient to have other facilities, such as checking the solution with examples. The low performance of PLS is apparently due to the fact that many PLS students could not proceed to other problems within two hours once they had trouble with one or two of the problems, because of the lacking of the hints and the needed feedback. Moreover, students using other systems may learn more from the hints provided.

About the sub-task nature of tutoring and tuteeing, there are some significant differences in the posttest results. Low performance of HTS is expected since students only need to watch the computer tutee, expand the DT when needed, and choose a hint for the student, thus is less intellectually demanding than tuteeing. In our interviews, most students said that they like tutoring the computer because it is an easy task and they agree that they should have learnt more if they had to do the problems themselves. Five out of six HTS students prefer teaching computer to a real student because it is easier. CTS students like having hints and some of them think that there are not enough hints.

Unlike other systems, all RTS students felt that reciprocal tutoring is like playing a game. Now, if CTS represents a typical ITS, then the performance of RTS is about the same as an ITS. One possible explanation for this is that in reciprocal tutoring, when the student plays a tutor, he or she regards the tutee as a counterpart of himself or herself. So the tutor also involves solving the problem, in a degree much larger than when in HTS, while at the same time being benefited by meta-cognitive activity — taking another person's position to watch throughout the process. Certainly, we need more investigation in this direction.

We successfully fooled two students who were asked to work on a 'distributed' RTS on two connected machines in different locations cooperatively; in fact, they used two independent RTS systems. This either implies that our approach of modeling a virtual tutee is psychologically plausible enough to the student tutor or students believed what we told them simply because they trusted us. The narrow bandwidth of the information between the communicating agents clearly contributes a part of this psychological plausibility. It is also possible that the student tutor does not have a good model of the computer tutee.

5. Discussion

Besides the centralized systems, we are also investigating two distributed reciprocal tutoring systems. One simply consists of two connected machines with a dyad taking turns to play the roles of tutor and tutee. Another one is a twofold reciprocal tutoring system. It consists of three connected machines with a triad participating three different sub-tasks. Detailed description of these distributed systems is beyond the scope of this paper. A very preliminary empirical trial indicates that there is possibility that the distributed systems may surpass the centralized systems. A reason for this perhaps is the interpersonal motivation or peer pressure generated in the cooperative learning process. Currently, we are moving these systems to Internet where the artificial learning companion is an option for the student to choose as a partner to cooperate, especially when there is no other student on-line.

Our current implementation of the simulated tutee can be improved in several aspects. For example, we can employ Bayesian net to represent the tutee model, instead of using the current simple concept list. Bayesian net provides a representation of more complex concepts and relationships and a mechanism of updating and making reference of the belief values. All the decomposed solutions can be represented more systematically in a single hierarchy of strategies in solving Lisp recursions (Greer & McCalla, 1989). To enhance the psychological plausibility of a virtual learning companion, task-related motivation may be modeled to reflect the tutee's feelings and attitude, for example, confidence and effort. Also, it is technically desirable to adopt a single student model to simulate both the tutor and the tutee.

Tutoring represents a range of actions, from simply lecturing, evaluating and diagnosing the tutee's answers, offering opinions, hints, advice, suggestions, and strategies, motivating the student, and even monitoring all parts of the learning activities. The tutoring activities discussed here only represent a small part of this range; yet, they promote meta-knowledge, such as strategic knowledge, judgment knowledge of the performance. This type of knowledge potentially fosters knowledge transfer, that is, learned knowledge to be applied to novel problems or domains. However, how to model this kind of knowledge and measure the learning effect are not easy tasks. Still, the preliminary evaluation indicates that reciprocal tutoring provides cognitive benefits that could possibly be different from other protocols of learning. More data and analysis are needed to answer important questions such as whether human learning companion is better than virtual learning companion or whether intelligent cooperative learning systems are superior to intelligent tutoring systems.

It is difficult to design game-oriented learning activities where the student can sustain motivation while paying effort to accomplish a learning task. The preliminary evaluation indicates that the reciprocal tutoring learning activity possesses some game elements. More observation is needed to reveal these elements and how they can be incorporated with the student model to enhance the motivational effects of reciprocal tutoring. Indeed, it is most desirable that all kinds of learning activities are motivational.

Reciprocal tutoring interleaves tutoring with tuteeing, or the vice versa, allowing immediate use of the learned knowledge and meta-knowledge of the domain. However, learning may also be proceeded in two phases: tuteeing followed by tutoring. An interesting scenario is that a student is being tutored by a computer tutor first, then trains an artificial agent so that its performance can reach to a level to defeat another opponent computer agent. Reversing these two phases, that is, tutoring followed by tuteeing, is also possible. This case can be regarded as a 'fading' process since the computer tutee partially does the modeling process for the student before the student works on the task (Collins, Brown, & Newman, 1989). In general, if learning by tutoring cannot perform well when stands alone, how it combines with other general forms of learning to generate effective learning paradigms remains a research question.

Finally, putting the computer in the position of a tutee and being taught by the student make the simulation of a virtual companion a salient feature of the system, and, as can be seen, approximating a typical student is technically equivalent to student modeling. Thus, the student model plays a critical role in designing reciprocal tutoring system, and, therefore, many cooperative learning activities. It dismisses doubts of the importance of the student model in cooperative learning (McCalla, 1990; Chan, 1991). Also, this work unfolds some different uses of the student model: When student model is used in traditional ITS fashion, it is a supporting component for the computer tutor (usually called the tutoring module) and is hidden from the student. When the student needs to teach another student or the computer, student model is a tool manipulated by the student to fulfill the responsibility of being a tutor. When the computer simulates a virtual learning companion, it plays as an active and autonomous agent inside the system. However, how the student model can become a general 'powerful' engine to be used faithfully remains to be a long term research problem.

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Making Distance Learning Collaborative

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Abstract

The paper outlines a way of study that makes distance learning collaborative, discusses the potential of and problems in computer support, and concludes by putting up a list of requirements to the design of computer support. The ideas presented build on ten years of experience with project organised computer supported distance learning at Aalborg University, Denmark, in which the authors have played an active role.

Keywords — Collaborative learning, experiential learning, distance learning, project organisation, problem orientation, CSCW, and CSCL.

1. Introduction

Collaboration as a goal of learning goes together with other learning goals such as integration of theory and practice and coping with uncertainty and change. As teachers at the Open University for ten years, the authors have experienced collaboration as a learning goal among the students. Most distance students are employed, studying part time. Quite often they make their employer pay their fee. Employers do this because they want to expand the organisation's potential for "organisational learning", while the students themselves want to expand their current professional competence. The wish to obtain collaborative skills is one instance where goals of the employers and the employees come together. "Organisational learning" is a concept put forward and given meaning by Argyris [1] and Schön [9]. Inspired by Bateson they emphasise the importance of generating double-loop learning through the questioning of assumptions. The skills required to engage in double-loop learning are skills that in a wider perspective enable humans to cope with uncertainty and take action in a multicultural and multivoiced and ever changing environment. Collaborative skills do not only make people responsive to, but more likely innovators of change, based on what Schön [9] has called reflection-in-action. Such skills do not necessarily come along with academic training. However, these skills are increasingly demanded among academic professionals.

The basic hypothesis of this paper is that the development of collaborative skills through academic learning requires a way of study and a study environment that:

(a) lets a group of students formulate a shared goal for their learning process

(b) allows the students to use personal motivating problems/interests/experiences as spring boards

(c) takes dialogue as the fundamental way of inquiry.

The project and problem oriented study form was implemented at Aalborg University as the overall pedagogic strategy twenty years ago as a response to experiental learning, the radical trend in pedagogy in Europe in those days. Today, it is no longer an experiment but forms a solid foundation for the university studies at Aalborg University, despite the fact that experiential learning is no longer the dominating pedagogical fashion, The project organised and problem oriented study form has proved its effectiveness as well as its efficiency on strictly economic and qualitative terms.

For the last ten years the project and problem orientation has proved its relevance also in the Open learning activities carried out in Aalborg. Most of the students at Open University want to improve or change career and enhance their ability for reflection-in-action, building on their professional experience. For these students the project organised and problem oriented study form offers a great opportunity, but also, especially with respect to time and location constraints, a challenge and some problems. The following is a brief outline of the foundation and experiences with problem and project oriented distance learning at the University of Aalborg, Denmark, especially with respect to how collaborative skills are acquired.

2. Basics About the Project Organised and Problem Oriented Study Form

Project pedagogy has been the working principle for university pedagogy at the reform universities in Denmark, respectively Roskilde University Centre and Aalborg University since the beginning of the nineteen seventies. In the founding days the emphasis was on the critical potential in letting the students take their point of departure in practical problems and personal experience. Today the project organised and problem oriented form of study simply seems to work well, providing high rates of accomplishment at a satisfying level of qualification. In contrast to the traditional university pedagogy building on lectures, information dissemination and self study, research [3; 8; 7, 2] have shown that the students through the project pedagogy develop the above mentioned "collaborative skills". Through *problem orientation, interdisciplinary, exemplary learning, participant control, project work* the students develop the ability of team building, critical discussion, reflection-in-action and the ability to take action in less structured and uncertain environments, and the students express in general great satisfaction and high motivation, in internal as well as in external quality assurance evaluations. Lately, in a ranking survey conducted by the largest newspaper in Denmark, the students at Aalborg University expressed the highest degree of satisfaction with teaching and learning among Danish students including those coming from traditional universities[1].

2.1. Theoretical foundation

While in the theory of organisational learning, collaborative skills are seen as important to obtain, they in the pedagogical theories behind project pedagogy are rather taken as a precondition:

The theory of experiential learning views learning as a social construction process. The German Marx-inspired critical pedagogical philosopher Oscar Negt [6] has suggested that the university may be viewed as an "emancipatoric room". Through critical (and ideology-critical) studies combining personal experiences with theory through the collaboration between teachers and students the traditional scientific paradigm is transcended and alternative scientific paradigms emerging. On the personal level, the learner get the chance of viewing her/his professional practice in the light of different scientific paradigms.

The theory of "situated learning" formulated by Lave and Wenger [4] takes apprenticeship learning as the archetypal instance of learning, and suggests that collaboration understood as legitimate peripheral participation in a practice is the most fruitful way of learning. Through participation the students informally and successively learn to deal with practice, to acquire the university culture and discourse.

The activity theory, coming out of the so-called cultural historical school of soviet psychology of the thirties suggests that learning takes place in spiral processes starting in outer experiments dealing with the material in a goal oriented way, preferably in co-operation with a more capable peer Vygotsky [10], continuing as a process of inteorisation and a further process of externalising, such as helping other less capable peers.

2.2. Pedagogical implementation

The idea of collaboration as the vital point also in learning at the university level, has, as mentioned, found a practical pedagogical implementation in the project organised and problem oriented study form as practised at the University of Aalborg.

The key principles of this pedagogy is - in addition to traditional theoretical academic training - to integrate three levels of involvement:

(1) The subjective condition. The problem has to be immediately meaningful and take as the starting point the experiences and the interests of the students

(2) The objective condition. The problem has to illuminate or reveal the historical and the societal circumstances of the problem.

(3) The action level. The problem shall point to action for the students, producing alternative ways of dealing with (professional) practice.

At the beginning of each semester the students are building teams in a problem formulation process driven by personal experience and/or curiosity. As they strive to investigate their problem, they - through the discussions with their supervisor - are faced with the scientifically theoretical and methodological demands that constitutes their discipline, as well as with the diversity of opinions and world views represented in the group. Since they are working on the same project and are faced with an examination of the project at the end of semester, the frustrations and break downs in understanding produced under these circumstances mostly turn out to be productive to the individual learning process as well as to the quality of the outcome, the project report.

Through their discussion the students develop skills to formulate a valid argument and judge its potential falsification, just like if they were students all on their own. Since they have to do it in a peer group, they at the same time are forced to take the argument further than they would dare to and be able to, being on their own.

The need of shared understanding stimulates the student's social imagination and enforces them to go behind every-day knowledge, seeking a shared view based on relevant information. In this process they de-

[1] Jyllands-Posten, April 30, 1995.

velop communicative (and meta-communicative) competencies, and the ability to participate in intellectual collaborative work process.

2.3. Organisational and environmental frame

The studies of the about 10.000 students at Aalborg University are organised in "themes", one per semester, and the basic elements of the curriculum are subsumed accordingly. The students form "storgrupper" (big classes) with a group of teachers attached. The themes constitutes the professional profile of the education. The themes focus on the core elements of the subjects (theories and methods) to be studied. The themes are organised in such a way, that increased and progressed knowledge and learning may be obtained throughout the study.

Within a theme, half the study time is spend on lectures and course activities (introductions and overview of the core disciplines) and half the study time is spend on collaborative project work (exploring a scientific and a professional practical problem in depth).

All students in a "storgruppe" share course activities while project work run in groups of five plus/minus two students. This way of organising provides a shared framework for the students' and teachers' discussion and inquiry, which although motivated out the students interests, is framed under supervision, so that a satisfactory level of insight in the curriculum of the discipline is guaranteed.

The implementation of the study form puts certain demands on the physical and organisational environment. For the group work to be effective it is necessary that each group have a study-room of their own, so that they can keep something like ordinary working hours at campus, go back and forth between the group room and the library and the lectures, have discussions and enjoy their meals in the canteen. Their "life" forms a platform of contact to the academic milieu and to older and younger students, which generates a lot of possibilities for informal, peripheral learning and socialising.

3. Project Organised Learning When Distant

At the spring term 1995, 1200 students were studying half-time under the Open Learning Programme at Aalborg University.

Two of these courses, Health care informatics and Humanistic informatics (100 students) are using computer conferencing, FirstClass, as the main communicative infrastructure. The courses are organised so that the students are offered a distance learning packet (against small payment) offering communication software, and modems.

The Open Learning courses are based on the concept of problem oriented project work. The idea of using FirstClass is to build a virtual university as a scientific community for the open university students and more specific to support the distributed students' project - and course work.

Besides using the conference system, students and teachers use other conventional media, and the students attend four weekend seminars in a year on campus.

At the first seminar they form groups around initial problem formulations and get introduced to the electronic communication facilities. Each group form at conference group in FirstClass, and the "storgruppe" forms one too. During the first "in-between period" the Open Learning students mostly use the project group as a reading and discussion forum, and prepare only a small pilot project to learn the methodology.

When they come to the second weekend seminar, they have established better social contact, and are able to reformulate the problem. Some re-grouping may take place. During the next in-between period they start doing more systematic inquiry, reading, literature- and information research co-ordinating different perspectives, often re-framing the problem. Some may do empirical studies, related to their work. At the third seminar they have a bunch of new ideas, thoughts, theoretical problems and questions they want to discuss with each other and the teacher. In the third in-between period they get on writing the project. They comment on each others' contributions, discuss and clarify argumentation and point of view, using FirstClass as their primary medium of communication. At the fourth seminar they get on discussing also drawing on the expertise of the teacher. The final period is used to finish the project and to co-ordinate the contributions of the group members. A group examination on campus, which takes its point of departure in the students project work, finally finishes the year.

Over the years - a BA takes 6 years - we see a decrease in the enthusiasm in the net-communication. People now know each other quite well, some want to work alone because they have special professional interests or certain working styles, while others become so fascinated by the academic knowledge presented, that they do not want to spend time on communicating with peers. However, even in those cases then, the students miss the shared knowledge building generated through the group-work.

4. The Effect of Mediating Technology on Group Processes

As stated before, collaboration as a learning goal and collaboration as a precondition for learning are two lines of thought, both leading to a study form that favours collaboration. In addition for those many students, who come to the university as mature practicians, collaboration is a way of overcoming two major problems: the problem of accommodating to the academic discourse and the problem of becoming part of the academic community living at a distance.

Making distance learning collaborative by means of computer conferencing is an attempt to overcome some of the problems related to distant students' out-of-campus-situation: The fear-related-to-building-a-new-identity-mechanism, which is always present in the students admission to the university, is pushed to its limits under distance learning conditions. Difficulties related to the formation of and entrance into the peer group of fellow students without having well-known interpersonal rituals for group formation at disposal, fear related to engagement in the academic discourse, the time and place constraints for students depending on company-employment, and last but not least the trouble building a shared understanding among students with multiple backgrounds, and located in multiple cultures.

Computer conferencing does of course not compensate for all the above mentioned problems. However, in combination with the project organised and problem oriented study form, it offers a new way of dealing with distance learning. Project work, even computer supported at distance, offers the students some kind of a safe base, a playground (or an emancipatoric room) where they may practice the academic discourse, exchange and explore their multiple backgrounds, learn about their different interpersonal rituals for group work and the different perspectives on the subject matter. FirstClass makes it possible to stay in continuously contact despite of time- and place constraints, and it enhances the possibilities of getting to know each other. FirstClass supports some of the work processes necessary for project work: collective messaging and informing, asking questions, exchanging statements, commenting on working papers and a broader access to a community of learners.

However, there are several problems too. Shared commitments and shared goals are always hard to obtain in team work, depending as they are on good faith, accept of intellectual and disciplinary differences, and time and motivation for collaboration. Under distance learning conditions it is even more difficult. Although FirstClass supports some of the activities related to project work, it has its severe limitations related to the narrow codes and the asynchronous communication. Problems which are well-known in the CMC-community. [5]

5. Collaborative Learning in a CSCW Perspective

Despite the fact that CSCW issues tend to relate to working life, and CSCL to the life of education, both the CSCW design community and the CSCL community may learn a great deal from reviewing the Aalborg experiments with project organised and problem oriented team work. The lessons to be learnt concerns the formation and daily work with communication and collaborations in teams in the perspective of (organisational) learning, and ways to accommodate the design of the computer support accordingly.

- Getting to know each other and each others' ways of working, and being aware of one's group mates' state of mind and being able to express one's feelings is important. To some extend a code for the personal aspects of communication develop over time, but sometimes too slowly, sometimes not in the most caring and supportive ways. A strategy (didactic) of enhancing communicative competencies in a distributed community would therefore be convenient:

- In order to enable the students to share goals, knowledge and understanding, when working together on the net, the CSCW-tools, in this case the conferencing system, have to support synchronous communication, in case negotiation of a social or subject oriented difficulty, or a potential misunderstanding may take place.

- Facilitation of work on shared documents, and the possibility of sharing literature electronically in a way that keeps personal comments and suggestions together with, but separable from, the formal writing, is also crucial.

- Since the negotiation of what is really the issue, is a prominent part of the project work, when it is problem oriented, a way of facilitating joint scenario-making and conceptual frame-work building would be an important step forward.

- The Aalborg experiences are made with FirstClass, a well working and well-known on the shelf system, reliable, but with few possibilities for tailoring. A programming environment, that would allow for tailoring together with or by the users, taking advantage of the energy and ideas growing locally, would be a real benefit. There are always major differences between teams and groups of teams in styles and preferences, and what means a push forward for some, is experienced as a lay back by others. Also, if technically smart enough, simply having to negotiate the facilities of the computer support will support the team spirit as much as furnishing and decorating the work environment when being physically together.

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TurboTurtle: A Collaborative Microworld for Exploring Newtonian Physics

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Abstract

This paper describes TurboTurtle, a dynamic *multi-user* microworld for the exploration of Newtonian physics. With TurboTurtle, students can alter the attributes of the simulation environment, such as gravity, friction, and presence or absence of walls. They can also manipulate the "turtle" (a movable ball) directly. Students can adjust its position, velocity and mass; change its kinetic and potential energy; and apply a force to it by strapping a rocket to its back. Through TurboTurtle's "group-awareness," several students, each on their own computer, can simultaneous control the microworld and gesture around the shared display.

This paper focuses on the rationale behind the major "group-awareness" design decisions made during our development of TurboTurtle.

Keywords — microworlds, groupware design, user interface design.

1. Introduction

Microworlds, or computer simulations of restricted environments, are an intuitively appealing way to promote discovery and exploratory learning [4]. One type of microworld, and the subject of this paper, simulates an adjustable Newtonian universe. In it, students can experiment with concepts such as gravity, friction, force, velocity, and so on, and see how changes in their value affect the objects moving within the simulation.

Microworlds—Newtonian or otherwise—are not new. They were first conceptualized by Papert in his 1980 book "Mindstorms," but in that era they were implemented as crude systems that required cryptic and error-prone command line interfaces e.g., Logo. In the 80's and early 90's microworld simulations became dynamic environments that students could alter on the fly, allowing direct manipulation of microworld objects. Smith's Alternative Reality Kit is one such example [5]. In this paper, we claim that another evolutionary step is about to take place: microworlds will become *group-aware*, actively allowing several students to view and manipulate the simulation.

We are investigating the application of collaboration-aware groupware technology and methods to build microworlds that re-enforce discussion by students around the learning tool. In TurboTurtle, each student has their own computer screen and input devices. They share the view of the simulation, have telepointers to promote deictic references and gesturing, and can simultaneously manipulate the microworld. Since students do not have to be co-located, we assume that they can talk to each other over an audio channel such as a speaker-telephone.

This paper presents the user interface of TurboTurtle, and discusses the design rationale that governed the development of TurboTurtle's group-aware features.

2. TurboTurtle's User Interface

To provide the context for our later discussion of TurboTurtle's collaboration-aware facilities, this section presents the single-user interface to TurboTurtle.

We wanted to provide a seamless interface that allowed all the student's cognitive effort to be directed at the contents of the microworld. Beyond the "see and point" premise of modern graphical user interfaces [3], we wanted TurboTurtle to make extensive use of sound, colour, and animation to capture the interest of young users.

What do students using TurboTurtle see and do? Figure 1 is a snapshot of a student's session. The lower half displays the simulation with the turtle being the ball at its centre. The turtle's location can be changed directly by dragging it with the mouse, and its direction and velocity altered by "throwing" it. The top of the figure shows a control panel, where tangible properties are set through constantly visible graphical sliders. These include the controls to change the turtle's size, mass, speed, the degree of friction and gravity, and so on. Students use the pull-down menus to access advanced features of TurboTurtle.

Within the simulation, the turtle's trail, a line of ink that follows the turtle's movement, can be switched on or off. The walls in the microworld can be changed as well. The turtle bounces off "hard" walls

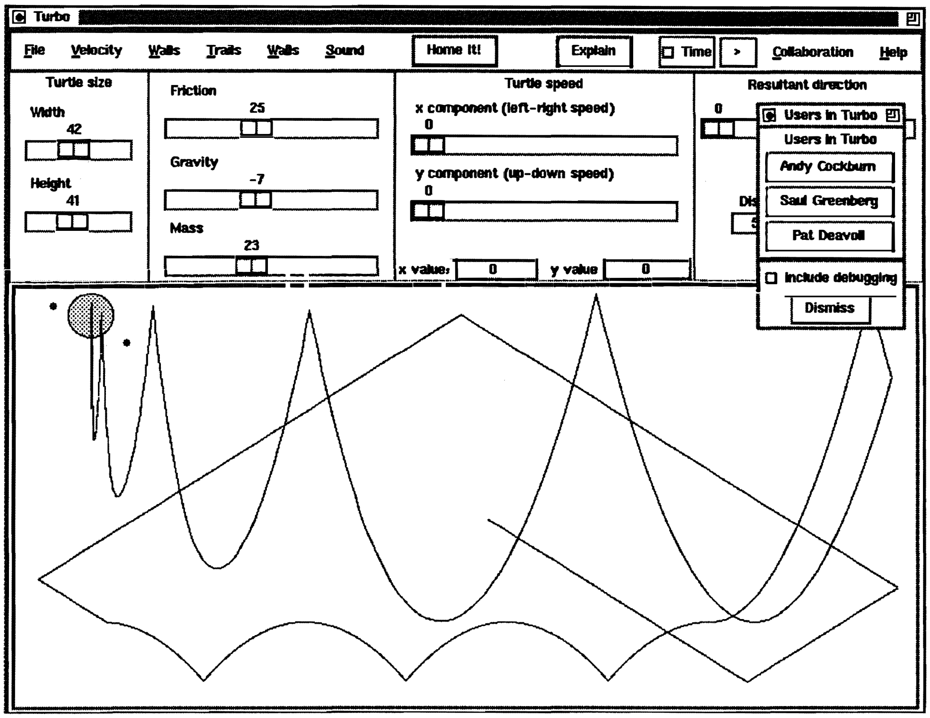

Figure 1: The main window to TurboTurtle.

and passes through "transparent" ones (which causes it to wrap-around the display). When only the ground is hard, the relative location of the ground to the turtle is remembered as it wraps through successive screens. Students can also display a mountain scenery backdrop, which provides additional visual cues to the altitude of the turtle. As the turtle gains altitude the backdrop changes to show smaller mountains, a row of aeroplanes, and then satellites. Of course, the trails and the mountain backdrop can be cleared at any point.

Figure 1 shows the turtle's trail after a series of user-driven changes to the microworld[1]. Starting in the middle of the screen, the turtle moved down and to the right with no mass or gravity. After seeing and hearing it bounce off the walls four times, the student added mass and positive gravity, causing the turtle to bounce under gravity (the sin curve). She then changed gravity to a small negative value, causing the turtle to bounce off the roof of the microworld. Finally, she added friction, causing the turtle to eventually slow to a stop.The microworld clock (set by the *time* button) lets the student freeze the microworld. This allows specific values to be set prior to running a new experiment. Time can run smoothly, giving a continuous real-time simulation, or discretely which allows students to scrutinise the change in variable values at critical instants. For example, the student could investigate changes in potential and kinetic energy by discretely stepping through the turtle's motion as it hits the floor and as it reaches the apex of its motion under gravity.

TurboTurtle is intended for students ranging from 7–17 years in age, and for peer groups where individuals have different knowledge and talents. TurboTurtle supports this wide range of abilities through two sets of controls: concrete and abstract. Concrete controls, which are continuously visible, present concepts that are familiar and frequently accessed by the youngest students (as shown in Figure 1). Abstract controls for more sophisticated manipulations are revealed on demand by mature users. For example, TurboTurtle lets advanced users view and manipulate values in Kinematic equations, which are selected as menu options in the "Laws" pulldown menu (figure 2). Choosing the first "Energy" equation creates a window into the microworld that dynamically displays the turtle's potential and kinetic energy. The second "Rocket" equation creates a control panel that allows students to attach rockets of varying force and fuel-time to the turtle, which lets them examine the inter-relation between force, acceleration, mass, gravity and friction. Other kinematic equation options provide dynamic simulations of the behaviour of a user-specified set of formula values: es-

[1]Naturally, the figure fails to show the turtle's movement, the dynamically changing slider values, the colour, and the audio output that are fundamental to the student's sense of fun.

sentially they provide an animated calculator.

Recoverability in TurboTurtle allows users to experiment with features, safe in the knowledge that they can get back to their starting state. Exploring a dynamic microworld is risky because it can change rapidly. In TurboTurtle, for instance, a student may arrange a group of slider values to simulate a rocket working against a certain friction, gravity, and mass. When the rocket is launched, the simulation runs and slider values will change to reflect the dynamically changing environment. In early trials of the system, we noted that students frequently forgot or mistook one or more slider values. When they ran the simulations, they were often immediately aware of their error, and found it annoying to have to reset the values that the system had changed. Similarly, students may be reluctant to change system parameters away from an interesting state for fear of corrupting them. TurboTurtle lets students recover from their ventures by allowing them to save and reload named states of the microworld. Of course, this is an explicit action that students must take, and they will likely do this for only highly interesting states. Allowing time to run backwards is also a type of undo, and is a high priority in our further work.

3. The Communal Microworld

TurboTurtle's group-awareness allows small groups of students (diads or triads) to simultaneously manipulate and talk about the simulation. This section is primarily concerned with the design decisions that governed the development of TurboTurtle's multi-user features. It begins with an overview of the system's group-awareness, and continues with the design decisions made[2].

In static images, such as the screen snapshot in this paper, collaborative use of TurboTurtle appears to be almost identical to single user usage. Group awareness, however, makes its style of use significantly different. In the description below we focus on these differences by assuming that two or three distance-separated students, each with their own computer, are looking at the screen and are talking to each other by a speaker-phone.

Each student sees exactly the same running simulation on their display. The turtles are in the same position and move at the same speed, the trails are in the same place, and the background scenery is identical. Similarly, the controls are *mostly* identical. They are in the same window location and have the same setting. However, students can decide to change their view of some of the controls. For instance, one could be examining turtle speed by its x-y components, and the other by speed and direction (Turtle meets Pythagoras!) Similarly, one could display independently some of the advanced control panels, such as the Energy panel.

[2]TurboTurtle's collaborative features are supported by GroupKit, a toolkit for groupware.

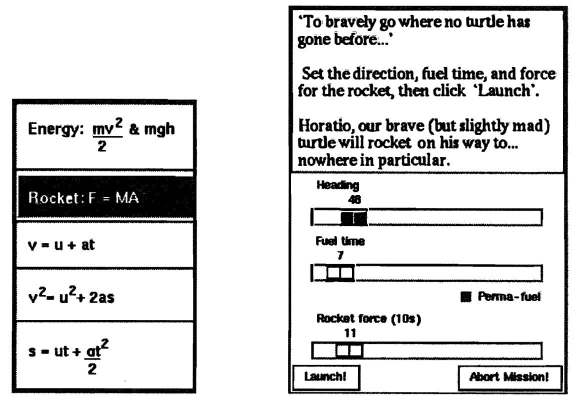

Figure 2: Selecting and using "formal" experiments in TurboTurtle. The 'Laws' menu, and 'Rocket' configuration options.

All students can work simultaneously doing anything they want at any time. For example, one student might move the turtle, while another adjusts its speed, and another alters the world's gravity. As in real life, they could even try to adjust the same control, which would cause it to "bounce" back and forth as they fight over its position! As any control is being adjusted, the new position is immediately reflected on all displays.

Students can see the other person's location on the screen by a *telepointer*, shown as the multiple cursors in Figure 1 (the dots by the ball). Not only is a student's own cursor continuously drawn and updated on the display, but so are the cursor's of their partners. A special menu option called "collaborators," presents a dynamic list of all the students in the learning session (Figure 1, top right). Pressing a student's name will raise an information window describing that student.

3.1. Design decisions

In spite of the conceptual simplicity of collaborative interface, many groupware design decisions had to be made. These included how students viewed the simulation, how they would control it, and how they could share their deictic references.

3.1.1. Viewing the simulation

What does it mean to have several students view the simulation? We considered four alternative approaches to view sharing:

(1) *Strict WYSIWIS views*[3]. Every student would view exactly the same thing on their display: the ball as it was bouncing, the changes in background scenery; the ball's location in the scene; the tracing of ball movements; and so on.

[3]What-you-see-is-what-I-see, or WYSIWIS was coined by Stefik *et al.*, (1987) in a discussion about a shared whiteboard system.

(2) *Relaxed WYSIWIS views.* While the state of the simulation would be the same, every student could have different viewports on it. That is, one student could be looking at (say) a zoomed out view, while the other could be zoomed in on a particular scene.

(3) *Unconnected views, same simulation parameters.* The parameters of the simulation would be the same across all systems, but the effects of the parameters on the ball would be local. This could simply be a matter of each student's computer moving the ball at its own speed, but since performance of the computers would differ slightly, so would the position of the ball. Alternatively, a student could create a smaller simulation room by shrinking the window, which means that the ball would be bouncing off the walls at different places and frequencies. In either case, the ball position in the simulation would differ across the views.

(4) *Unconnected views, different simulation parameters.* The parameters of each student's simulation would differ, thus affecting not only the position of the ball on a local display, but its overall behaviour as well.

We wanted the view to act as a conversational prop providing a focus for the students discussion [2]. We thought the strict WYSIWIS view would be the best choice to encourage this. The display becomes a shared cognitive artifact, and speech references would remain within the context of the shared image. Strict-WYSIWIS would allow students to pose questions and comments to each other such as "why did the ball bounce that way?" or "the ball just moved into outer space" or "look at the shape of the trace."

In contrast, views 2 through 4 would cause progressively greater breakdown in the discussion, probably resulting in greater confusion and ultimately less interaction between students (a similar observation was made by Tatar *et al.*, [8]). Relaxed WYSIWIS causes people to ask "can you see this" or respond "which one?" Students using the unconnected view with the same parameters would have to explain what their ball is doing on their display. With different parameters, they would also have to explain the settings.

Although the relaxed and unconnected approach does give the student the ability to customise their view, the strict WYSIWIS view seems preferable as it reinforces the microworld's role as a conversational prop.

3.1.2. Controlling the simulation

The simulation is directed by manipulating the controls on the control panel: sliders, buttons, menu selections; and by directly moving the ball position in the view. Given a strict WYSIWIS view and identical simulation parameters across the system, there remain several options for presenting the controls and for having students interact with them.

First, how do students view the controls? Controls could be identical on all displays (strict WYSIWIS), or different students may see different controls in their view (relaxed WYSIWIS). The choice is not as clear here. In a complex simulation system such as TurboTurtle, the number of controls, including the pull-down menus and the pop-up panels, are huge and can clutter the display quickly. It seems reasonable to have a strict WYSIWIS view of the primary controls, while having a relaxed WYSIWIS view of advanced controls.

Second, how do students see the setting of a changed control? In a "parcel post" model [8], the changed value of the control would be delayed until the student had completed their action. For example, if one student adjusted the gravity slider from 0 to 20, the other student would only see the slider jump instantly to 20. In contrast, the "interactive" model causes the control's state to be transmitted as it is being manipulated. Sliders move, buttons get pressed, pulldowns selected. Clearly, the interactive model is preferable, as students will be able to see the changes as they are made, and are less likely to miss the actions of the others.

Finally, who has permission to use what controls? Several choices are possible. Students could be assigned to a mutually exclusive subset of controls. A turn-taking model could be enforced, where only one student at a time can manipulate the controls. Or students may be allowed simultaneous access to all controls, constrained perhaps by some mechanism to minimise confusion if two people try to manipulate the exact same control. We have opted for simultaneous access because we believe it will encourage each student to explore and control the simulation. Anyone is allowed to do anything at any time. The key to making this work is to provide rich dynamic feedback between students that leaves them constantly aware of each other's actions, and encourages them to talk.

3.2. Telepointers

In summary, students have mostly the same image of the core controls, with advanced controls being optional to avoid screen clutter. Anyone can manipulate any control at any time, and all user's manipulations are constantly visible.

Deictic references allow people to point to things and refer to them using words such as "there," "this one," and "that" [8]. A strict WYSIWIS view by itself does not provide enough information to let students understand each other's deictic references, for they cannot tell what part of the screen they are attending. Breakdown of deixis has been a common failing of groupware [8].

The easiest way to support deictic reference is through *telepointers* [1,7], which are cursors, one for each student, that are continuously visible on all displays (as in Figure 1). Telepointers are useful in microworlds for deictic and other types of references. First, they act as a locus of attention; one student can assume that the other is directing their gaze at their cursor. Second, they become an artifact that they can talk around e.g., the phrase "look at this" is tied to the spot on the screen that the person is pointing to. Third, their animation becomes a gesture. For example, a student circling an area of the screen tells others to attend to all of the items in that area. Finally, they provide a cue of someone's intent. If the telepointer is moving towards a slider, then one expects that the next action could be to change the setting of the slider. This helps mediate who is doing what on the display.

Telepointers were included in all parts of TurboTurtle. People can gesture around the shared view, focus attention to settings on the control panels, and implicitly indicate both their intent and their action when manipulating a control.

4. Summary

There are many directions for further work in TurboTurtle. With respect to refinements of the microworld, the world's our oyster: there is no obvious end to the types of domain that can be covered by a group-aware simulation. There is, of course, much to be done investigating the nuances of adding collaboration to CSCL. To date, our design of TurboTurtle has been primarily motivated by technical interests. Although we have run adhoc usability studies that detect the "large grain" usability flaws, we have yet to take TurboTurtle to the battlefield. We are very aware of the disparity between a designer's expectations of use and the end-users' behaviour. Extensive observation of TurboTurtle in use is required.

Acknowledgments

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Availability

TurboTurtle is available directly from the first author of this paper.

Equity Issues in Computer-Based Collaboration: Looking Beyond Surface Indicators

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Abstract

Student equity issues in small-group, computer-based design work carry all the same problems as other kinds of cooperative group work and some special problems related to the computer itself. This paper centers on the relationship between access to the computer mouse and other factors in group interaction in order to gain a fuller understanding of processes that may underlie inequities. This exploration is done in the context of two case studies from the Middle School Math through Applications Project (MMAP). Implications for classroom organization are discussed in terms of a theory that focuses on meaning-making rather than black-box structuring.

Keywords — Equity, cooperative learning, mathematics instruction, computer-assisted design.

1. Introduction

The use of the computer as a tool during cooperative group work has added some new dimensions to the problems of equity and status differences (Cohen, 1986). First, most of the questions about small group work are no simpler with the computer than without, and second, the computer's particular characteristics make some problems even more thorny. For example, we wonder how can we be sure all students are participating in an activity. When all students had access to a common set of manipulatives, we could at least look for hands-on behavior as a sign of participation. With the computer, we must sometimes depend on fleeting talk and focus of gaze as signs that a particular student has engaged with the task at hand. When we look at a group of students around a computer, it is hard to know if the student interacting most directly with the computer is also the student doing most of the thinking and problem solving.

If we assume that the person interacting most directly with the computer is also doing the lion's share of learning, inequitable access to the computer becomes much more serious than a lack of exposure to technology; it becomes a lack of exposure to the curriculum itself. This problem has not gone unnoticed and considerable research has been done in the cause of exploring devices that can help ameliorate problems of differential access to the computer. In particular, the widely-held assumption that males tend to dominate computer-based interactions has led researchers to explore the effects of the gender composition of small groups on the outcomes of group interactions.

For example, Lee analyzed same-gender and mixed-gender groups working with the program, *Where in the World is Carmen Sandiego.* The study found differences in such factors as the amount of task and procedure-related help given and received, based on the gender composition of the group (Lee, 1993). Other studies have found that the task itself can reverse the effects of group gender composition, with different effects found for a language-arts cloze task than for a LOGO programming task (Underwood & Jindal, 1994). Cohen, in a meta-analysis of non-technology based group work studies, claims that different rules apply depending on whether the task is well-structured or ill-structured(Cohen, 1994). Other research indicates that groups with the most ideal gender-structuring may still run afoul of equity problems due to idiosyncratic factors in group composition (Hoyles, Healy & Pozzi, 1994). This study found that initial interpersonal hostility in a group affected the way the group organized the work, which in turn affected the group's productivity and the roles each individual was able to play in the product.

Research such as that cited above may be able to help us to alleviate gender-related equity problems. However, such research has revealed the problem of organizing groups to promote equitable access to be quite complex, calling for different organizations depending on a large variety of interpersonal and task-related factors. This leaves teachers in a difficult analytical position when they actually try to set up groups in their classroom, because they must try to decide which of these factors apply to their own situation. As researchers, we have not provided enough underlying theory of group process to help teachers and students evaluate and improve their particular group process as it evolves. Instead, we have provided an ever-lengthening list of black-box rules.

In this paper, I hope to contribute to underlying theory by more closely examining the problem of differential access to computers. More precisely, this paper looks at access to the computer's mouse to see what the role of the mouse is in group interaction, using two case studies taken from the Middle School Math through Applications Project (MMAP). In MMAP, students use the computer as a tool for architectural design, working in small groups.

The MMAP cases serve as a good entry into the problem of mouse access because MMAP teachers, researchers, and students commonly center on the mouse as a signal of who is controlling design sessions on the computer. One teacher, for example, declared alternate days "boy's day" and "girl's day" on the mouse when she saw that most mice in the class were held by boys. Almost all our teachers encourage, remind, or admonish students to share use of the mouse. The students themselves also seem, to varying degrees, to attach some importance to who holds the mouse. They pull the mouse away from one another, complain when one of them monopolizes the mouse, and reach for the mouse almost automatically when they want to bring their ideas to reality on the computer.

Given the importance attached to mouse possession, the assumptions behind the actions of students and teachers bear closer examination. What happens when a child holds a computer mouse? Does the mouse mean power? What happens when a child who seems to be dominating work holds the mouse? What happens when a child who seems to be hardly participating holds the mouse? What happens when she never does? What does an inequitably-organized group look like? How can a teacher best help students to work equitably, given that she can only glimpse snapshots of their work sessions as she tries to keep up with all the groups in the class? By understanding more about group dynamics around a computer, we can learn more about group work in general, because the mouse serves as such a strong and outward marker. Since only one child at a time can hold it, it serves as a symbol of control over the group product, whether or not this control is real.

This paper examines the work of two student groups involved in a MMAP computer-based design project. It describes the relationship between who held the mouse and what happened in the group. These relationships turn out to be much more complex than one would expect given the assumptions about mouse possession and group control. After presenting the two cases, I'll discuss the implications of these cases for improving equity in mathematics classes that rely heavily on collaborative, computer-based work.

2. Case 1: Donald's Group

In the first case, Donald, Michella, Paul, and Mark are working together around the computer to make their first draft of an architectural design. The design is for a research station in Antarctica that will house four scientists for two years. We call this group "Donald's group" because Donald has a way of appearing to dominate work in the group he's in. He is proud of his computer skills and of his home computer. He happily engages in rivalries with anyone who disagrees with him, and he likes to win, but he always argues with a smile. I analyzed a video tape that was taken on a day when Donald had just been reprimanded for taking over group work. During the seven minute design session, Donald holds the mouse for almost 4 minutes (53% of the time), while the other three group members divide the remaining time. But part of the way through the session, the teacher visits the table and makes Donald give the mouse to another group member. The question is, did this intervention make the group more equitable?

Close analysis of this group's talk shows that the person with the mouse often has less impact on the design than other group members. As soon as one member takes the mouse, the others start shooting instructions at him or her. Mouse holders have all they can do just keeping up with this flurry of instructions. For example, consider the following piece of transcript from a part of the session where Donald has the mouse. Michella, Paul, and Mark are all using talk to guide Donald's use of the mouse as they create the design on the computer:

> Michella: OK, I want a door first, and then once you open it,
> Donald: A door?
> Michella: Yeah.
> Paul: A door, and then there's a hallway.
> Donald: In the middle?
> Paul: Yeah.
> Michella: Yeah. Wherever you want to put it.
> Donald: A door? In the middle? Of the hallway?
> Paul: Yeah.
> Paul: Not that small, not that small.
> Michella:[laughs]
> Paul: No. erase it.
> Donald: Why?
> Paul: Up more.
> Donald: Up more? No, this isn't the corner, this is a hallway.
> Mark: Stupid little house...
> Michella: So once we walk in it's a big old hallway.
> Paul: (?) kind of hallway.
> Michella: between all that hallway you can see
> Mark: a walk-in closet.

Michella: Be quiet!
Paul: (?) go straight.
Michella: And then you turn and you see,-
Paul: Keep going,
Michella: - you see the living room.
Teacher: (to whole class) You've got one minute left to just get done the basics.
Mark: Hurry up!
Donald: OK.
Mark: how many floors are we making?

Although Michella doesn't have the mouse, she is clearly having a great impact on the design. She is giving a verbal walking tour of the design she is picturing, and Donald is more or less drawing it on the computer. Others are also having their suggestions heard and used.

Soon after this, the teacher comes over and sees that Donald has the mouse. This results in a reprimand, especially because Donald has just been chastised for dominating the group's off-line work earlier in the class period. The following exchange takes place:

Teacher: Now why is Donald running this? Does Mark never get an opportunity too?
Mark: (?)
Teacher: Donald you get (?) away from the computer.
Donald: Paul said he didn't want to. (pushes the mouse toward Mark. Mark takes it and makes 3 wall sections.)
Teacher: Now wait a second you just pointed at Paul you didn't point at Mark. How bout Michella?
Mark: here you go.(Mark gives Michella the mouse).
Donald: Yeah, Michella!
Michella: (grins) I didn't -
Mark: I created my own house.
Teacher: Michella needs an opportunity also to be on the -
Michella: OK, so I want
Paul: The living room.
Teacher: So you go ahead and you make some decisions for them, cause they make a lot of decisions for you,
Michella: I make decisions!
Teacher: So go ahead for now,
Paul: Don't put a window there!
Teacher: So go ahead for now, and make some decisions for them.

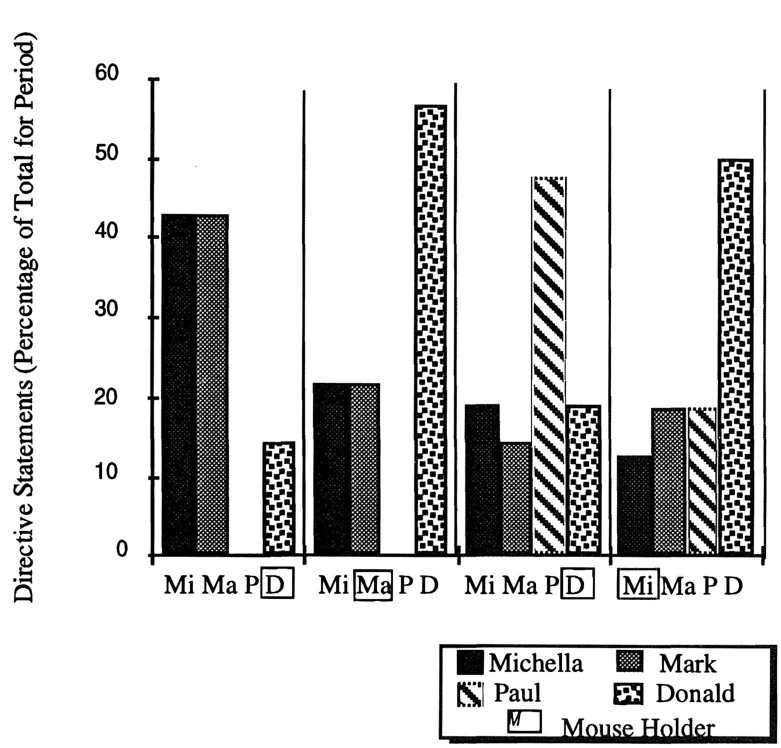
So the teacher has not only given Michella control of the mouse, but has encouraged her to take a dominant role in the design. But this turns out to be difficult, as Michella tries to balance the role of designer with the demands of using unfamiliar software.

Michella: (laughs) where's the door at?
Donald: Dooor, next to the bulldozer,
Michella: I see it.
Paul: You found it.
Donald: OK.
Michella: I hate this.
Michella clicks, and after a few seconds everyone laughs.
Michella: how do I erase it?
Donald: You sound like Mark! no, not Mark, but Martin.
Paul: This door, or this door?
Donald: Oh my goodness, (might be imitating Michella)
Mark: (?) none, bulldozer [The bulldozer is a tool for erasing]
Michella: I want..
Donald: bulldozer
Michella: It don't work.
Donald: Now get rid of those two doors.
Mark: Three doors.
Michella: I rather like them like that, shut up. [She goes to erase them anyway]
Paul: So are you putting number one or number two?
Michella: oh, why they ain't working?
Donald: You got to put the arrow part, you know the little tip, tip, tip, tip
Michella: No one does it!
Mark: bulldozer, it's on bulldozer.
Mark: You guys are on-
Donald: The-e-e-ere! (applauds)

Between the mechanics of the computer use and the suggestions of three group members, Michella is less able to have impact on the design than she was previously.

One measure of participation which seems valid for this session is the number of suggestions, commands, and ideas voiced by each member of the group. I'll use the term "directive statement" to refer to all of these. Figure 1 shows the number of directive statements made during each phase of the session, with the phases delimited by change in the holder of the mouse (or keyboard if it is the primary input device).

Figure 1: Directive Statements Versus Mouse Possession



Donald's use of directive statements drops considerably when he has the mouse, and rises again after he gives it up. Michella's total also drops when she gets the mouse. Also, as the above transcripts show, the level of her talk also changes. She spends more time on small details and less on conceptual design.

In this case, the teacher's intervention had precisely opposite its intended effect of putting Michella in charge and limiting Donald's impact on the design. Michella did try to resist letting the others take over, but the demands of running the computer were too great for her to be effective. Does this mean that a teacher shouldn't intervene in such a situation, or that the mouse is never an indicator of control? To provide more context for exploring these questions, I'll present an analysis of another group working in a different school on a similar task. This group is similar to Donald's group in that one boy tends to talk more and hold the mouse more than the other group members. Then I'll draw from both contexts to provide a framework for interpretation.

3. Case 2: Mitch's Group

The second case is taken from a group's first day using the ArchiTech software that serves as a design environment in some MMAP units. ArchiTech allows students to draw floor plans. and analyze them for characteristics such as cost and energy efficiency. One boy, Mitch, has been trained in the software, and his job is to help his group members, Darlene and Yuji, come up to speed in the software while the group works together to design a floor plan. He (along with all the other students who serve as trainers for their groups) has been told to help by facilitating group member's use of the software, not by doing everything for them.

Nonetheless, Mitch holds the mouse for eleven minutes during nineteen minute session. He also makes more directive statements than the others. He follows Donald's pattern of making fewer contributions to the design when holding the mouse, but only during the first half of the session. Darlene holds the mouse for only two minutes, with Yuji holds it for the remaining six minutes. Like Michella, Darlene has trouble making contributions to the design when she is holding the mouse. The next set of transcripts allow us to compare Darlene's role in the conversation when she is not holding the mouse to when she is holding the mouse.

In the first transcript segment below, Mitch is holding the mouse. Darlene suggests a bathtub and shows Mitch where it should be placed. Yuji joins in and directs Mitch about the size of the tub. The interaction continues similarly, with Darlene and Yuji directing Mitch's use of the mouse.

Darlene: Put a bathtub right there.(points)
Yuji: A big bathtub.
Mitch: A bathtub.
Mitch: How big do you want the bathtub?
Yuji: Big.
Mitch: Where?
Yuji: Right there.(points.)
Darlene: And then put a tiny little sink.
Mitch: Right here?
Yuji: Yeah.
Darlene: Yeah.
Mitch: Like that?
Yuji: A little bit bigger.
Yuji: Ah, that's good.
Darlene: Yeah put it, and then put a sink in.
Mitch: We have to make a door first
Darlene: Oh, yeah.
Mitch: The door 'll be right there?
Darlene: Yeah.
Mitch: OK?
Darlene: Yeah. and then put a sink up.
Yuji: No, door right here. door right here.
Mitch: In the corner?
Yuji: So it sits right here. Yeah.
Darlene: That would look funny, though, you walk in a corner, you go out of the corner?
Yuji: Yeah that's it.

Darlene has an active and directive role in this conversation. She suggests two design elements, a sink and a bathtub, which are taken up by the group and collaboratively incorporated. Now compare this to her role when holding the mouse. She takes on a much more subordinate role, while Mitch almost seems to be controlling the mouse verbally through Darlene.

Mitch: Now make a big humongous doorway, like a double door.
Darlene: OK, a door,
Mitch: Make a really big door.
Darlene: Where?
Mitch: Right there.
Mitch: Big door big door bigger bigger, down down down down.
Darlene: You want it to open like that?
Yuji: No. the other way. Rotate it.
Darlene: OK, now one more.
Yuji: Another door. Make it a double door.
Darlene: Another door? OK.

At this point Mitch takes the mouse again, which bodes well for Darlene's participation in the design. Altogether, she has more of the elements she suggests accepted into the design than either of the other two: Darlene has ten elements accepted, Yuji has nine, and Mitch has seven. In fact, this order is precisely opposite from the order of time on the mouse (Mitch, Yuji, and Darlene). In this group, the more time a child spent on the mouse, the less he or she had elements accepted into the design, as shown in Figure 2.

4. Two Cases: What We Can and Cannot Abstract

These cases are similar in that they highlight the kind of group interaction that commonly signals gender-related problems to most observers. Anyone walking around the classroom, especially a teacher who is familiar with the behavior patterns of particular students, would probably glance at either of our two groups and conclude that an assertive boy was dominating the group once again. The teacher actually drew such a conclusion in Case 1. The group in Case 2 also received a visit from the class's student teacher a little later in their interaction, in which the teacher admonished Mitch to share the mouse. The group proceeded to ignore his request and the student teacher moved on.

Yet, we have seen in both cases that our inequitable situations were at worst more inequitable in technology access than in curriculum access, and at best barely qualifying as inequitable at all. The two girls in the case studies had the most access to the design task precisely at the points at which the group looked most inequitable: when the boy with a reputation for dominance held the mouse.

Does this mean that we should restructure all small groups so that assertive boys hold the mouse? Of course not. In MMAP, we have also observed groups that fit the pattern of our expectations quite well: the person holding the mouse actually *was* shutting other group members out of the design task. The point to be draw from these examples is that surface indicators alone, as convenient as they may be, cannot tell us at a glance whether a group is working well together, and that interventions based on these indicators may have effects precisely opposite to what we intend, as in Case 1, or no effect at all, as in the student teacher's visit to the Case 2 group.

5. Conclusion

Whatever role the mouse plays in group dynamics, it is certainly not a reliable indicator of control over group collaboration. This is true for both kinds of control usually noted in research: task management and control over the design itself. The person who held the mouse most did not in any important sense control either task management or design features. In fact, the very notion of control becomes difficult or impossible to pin down when complex group interactions are examined closely. We might just as well ask who is in control in a bumper-car ride– the answer would be everyone and no one. Suggestions made may or may not be accepted, and design elements accepted may or may not be suggested aloud. Ideas, once suggested, can grow and take shape as the group tries to draw them, moving far from the original idea. Certainly the computer is a partner in the collaboration, since students often have to think of alternatives when their ideas can't be represented properly on the comp uter.

Still, what is one to do with the fact that Darlene and Michella both had less access to the computer than the rest of their group? There are two potential problems. First, will these girls develop computer skills? And second, do they perceive the mouse as a signal of control, and thus feel disempowered?

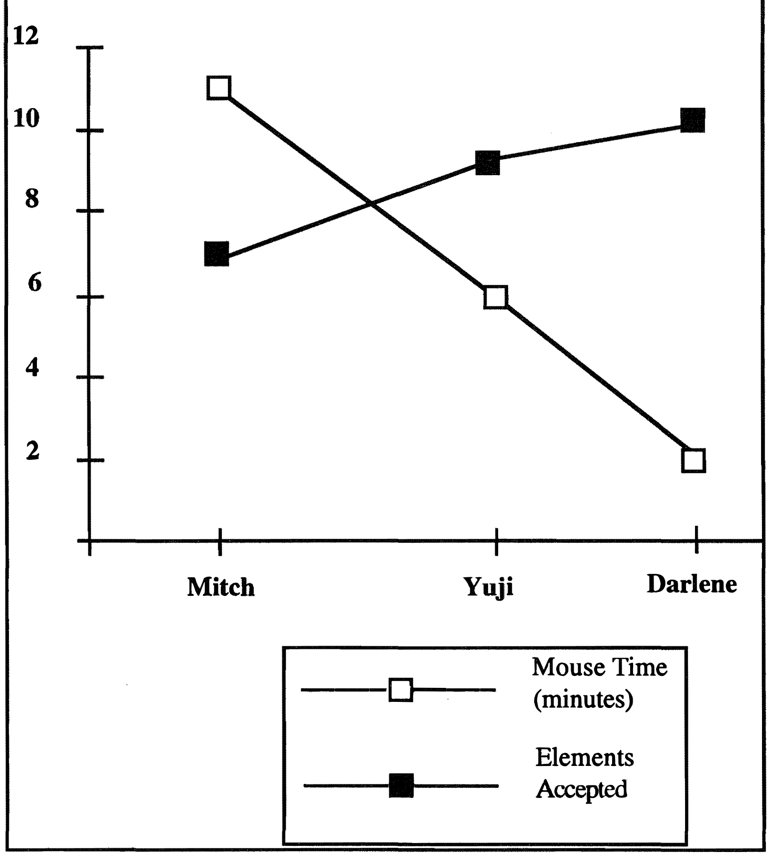
In Darlene's case, she was able to function quite well on the computer when the boys were not around. On one day she completed an entire design on her own, and showed the results off to a friend. Our observations in many groups subsequent to this suggest that whenever students are fairly involved in the design, they pick up computer skills by watching and can come fully "up to speed" with a little time for exploration.

The second problem is more disturbing. Darlene did apparently feel that her role in the design was less than the boys' role. In her group presentation (two months after the session analyzed) she said the boys did all the work and she and another girl sat in the back and made suggestions. However, the fact that Darlene had less time on the mouse and the fact that she felt that she had less impact on the design are twin symptoms of the general disempowerment of girls in math class (Koehler, 1990). This problem is so pervasive that mandating mouse control, even if it did actually help the mouse holder control the design, wouldn't erase the general inequities.

What we can do, however, is to help students become more conscious of what good group collaboration is, and what they should expect from other group members and for themselves. If students are encouraged to work out compromises and to find their own productive role in the group process, then they are much more prepared to become productive members of collaborative adult work groups than if we try to engineer solutions for them by telling them who should hold the mouse and what role they should play in the design process.

Cole (1995) sheds some light on why surface level structuring may have the unpredictable effects explored in this paper. That study traced the development of meanings for participants in small

Figure 2: Mouse Time and Design Elements Accepted



group computer based design work. It found that every aspect of the group's interaction, from academic content to social roles, developed meanings through the process of group interaction. These meanings came from places as varied as interactions with teachers, long-practiced social roles, and roles copied from other participants within and outside the working group, as well as from previous academic and non-academic experiences brought to the group. All of these factors became influential when a participant injected them into the public forum, creating a pool of meaningful concepts and behaviors that others could draw out, modify, and reinsert into the public pool. In this way meanings became increasingly elaborated and sophisticated for participants.

Thus, a behavior such as mouse possession will never have an unambiguous meaning. Not only does the behavior differ in meaning from group to group, but it differs within the same group over the course of the group's interaction. That is, the mouse serves as a symbol of group control when one or more of the participants use it that way. In the same group, the mouse can serve as a symbol of subordination when the participants treat the mouse holder as subordinate to group instructions. In short, the way the mouse gets used in a group has much more to do with the interpersonal meanings brought to the group and developed during interaction than it does with whatever properties are inherent in the mouse, (e.g., the fact that only one person holds it or that the holder has most direct access to the computer).

In Donald's group, the mouse did not even begin to become a symbol of group control until the teacher explicitly gave it that meaning. In fact, Donald was deliberately playing a subordinate role by holding the mouse and volunteering to follow the other participant's instructions. When the teacher came over and told Michella to take control by taking the mouse, Michella at first protested that she was active in the design process ("I make decisions!"). But she did take the mouse, and found that the teacher's interaction with the group was not enough to overcome the pattern of behavior that had already become established in the group's organization. That is, she and the other participants continued treating the mouse holder as the one who implements other's instructions, just as they had when Donald held the mouse. Over time, as everyone acquired more facility with the computer program, it is quite possible that the meaning of mouse possession might have changed again for the group, depending on such factors as how the social interaction played out, what happened to the group's design when they showed it to the class, and how much particular participants felt that they had impacted the design.

In Mitch's group, the meaning attached to mouse possession was even more ambiguous. During the initial interaction, an organization developed in which each member of the group claimed a room to draw. The person who claimed the room also expected to hold the mouse during the drawing of that room. Yet this organization was in some conflict with a pattern that came about because Mitch had been the participant who learned how to use the program first. In the first part of the interaction, he took on the role of running the program while others gave suggestions, and this pattern also became part of the group's interaction. When Darlene took the mouse and found it much harder than before to continue to design "her" room, she relinquished the mouse to Mitch, choosing the role of room designer over the role of mouse holder when the two came into conflict.

It is easy to see how, with the number of factors that impact the meaning of the mouse, that simple one-time teacher structuring might not have the expected impact. Teachers must build meanings the same way as any other participant in group interaction, by inserting them into the public pool, often multiple times, until they are taken up by other participants. In (Cole, 1995), teachers *were* able to influence complex behavior patterns in groups, but only after they had emphasized and demonstrated the pattern themselves many times and only after the pattern was taken up by other participants and molded to fit existing interactional factors.

Thus we must ask ourselves two questions in considering equity in computer-based interactions: First, what behavior patterns we are really trying to build, and second, how can we place these behaviors in the public forum so that they are most available to be taken up by students? Since sharing the mouse is just a symbol of the behavior of working cooperatively, we should think about how to raise awareness of what it means to work cooperatively. This way that students can evaluate and remedy their own group processes in ways that correspond to the behaviors and concepts that make sense in their own groups.

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Applications to Support Student Group Work

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Abstract

Group projects form an important part of learning in a university environment. Potential group members can identify learning advantages of participating in group work but also both anticipate and then experience problems which affect the performance of student groups. Students and staff at the University of Canberra have collaborated to design groupware support for student project teams. This paper discusses the types of activities involved in student group work, describes the kinds of software support that are being trialled to facilitate learning through group work activities, and summarises an evaluation procedure.

Keywords — Groupware, collaborative work, student projects, Lotus Notes.

1. Group Work Activities

1.1. Advantages and Problems

Our students are required to work in groups of typically four or five to undertake project work, for example, the development of a report or an information system. About half of our students study part-time and are rarely on campus. Our students come from a variety of cultures and countries. Group work is important for a number of reasons identified by students, staff and graduates [2], [3], and some of these reasons are that group work:

- enables projects of a realistic size to be undertaken
- reflects a requirement of employers that students be experienced in group work
- allows more variety in the design task
- enables students to learn from each other.

Potential and real problems with student group work have also been identified [2], [3] including:

- mis-match of goals and expectations of group members
- cultural differences leading to different ways of communicating and contributing to group work
- unequal contributions to group work by some members
- difficulties in meeting because of problems with both the time and possible location of meetings.

At the University, we have several ways of supporting group work including a special meeting room with an electronic whiteboard where a group of students can record and share ideas. However, additional means of support, whereby some face-to-face interaction can be replaced or supplemented by work at different times or from different places (e.g. home or work) is seen by both staff and students as desirable [2]. This paper focusses on the design and evaluation of groupware support to facilitate these activities.

1.2. Dimensions of Group Work

Group work encompasses a wide variety of activities, carried out in a variety of ways for a variety of reasons. Figure 1 summarises some of the issues. This categorisation was done collaboratively, reviewed with peer experts and is consistent with the work of Mandviwalla and Olfman [5].

Structure	Domain	Purpose	Activity
Formal Informal	Sub-group Whole group Outside group	Task performance Social, Group cohesion	Conversation Discussion Development of deliverables Records management Project management

Figure 1. Dimensions of group work.

Student group work can be structured in one of two ways:

- *Formal Group Projects.* In a formal group project, the group is jointly responsible for the production of a deliverable of some sort, e.g. a report. The composition of the group is fixed for the duration of the project, typically three to eight weeks.

- *Informal Collaboration.* Two or more students choose to work together on some aspects of their work. They are individually responsible for any deliverables (e.g. assignments). The length of the collaboration is variable (from a single discussion to an entire course), and membership of the group may change over time.

Within a formal group project, there are always areas in which informal collaboration occurs, so any groupware support must address both the formal and informal dimensions.

Group interaction is not limited to meetings or activities involving all members. It also includes activities involving only some members of the group, such as holding private conversations, or forming smaller groups to carry out specific tasks, interactions with other groups, for example comparing notes on common problems or discussing results, and contacts with other people external to the group, e.g. approaching a tutor or a Help Desk for advice.

Group interaction should not be seen as limited to the performance of the prescribed task. Groups also spend considerable effort on social interaction, and on group formation and maintenance activities. Group formation activities are critical in the early stages of any group project, and require exploration of other group members' background, abilities, and interests. Face-to-face meetings are crucial during this phase, while electronic forms of interaction may be able to play a more significant role later in the project.

In the following sections, we discuss the activities that take place during group work. The emphasis is on task-related activities in formal group projects, but the activities involved in informal collaboration, to support group cohesion, and in liaison outside the group are similar.

1.3. Typical Group Project

As a typical example of a formal group project, we will use a group having to prepare a lengthy report over a period of a few weeks. The project is assumed to be large enough to require both discussions within the group, and significant individual work on components of the final product. It is possible to identify five main classes of activity:

- private conversations between two or more group members

- discussion of issues, content and structure of the deliverable

- development and review of the deliverable

- storing work in a repository or referencing such work

- task allocation and monitoring.

The second, third and fourth of these are *operational tasks,* in that they are directly concerned with the production of the deliverable (the final report). The fifth is a *management task,* and is concerned with organising the allocation of work within the group and monitoring its progress. Figure 2 summarises the last four of these activities.

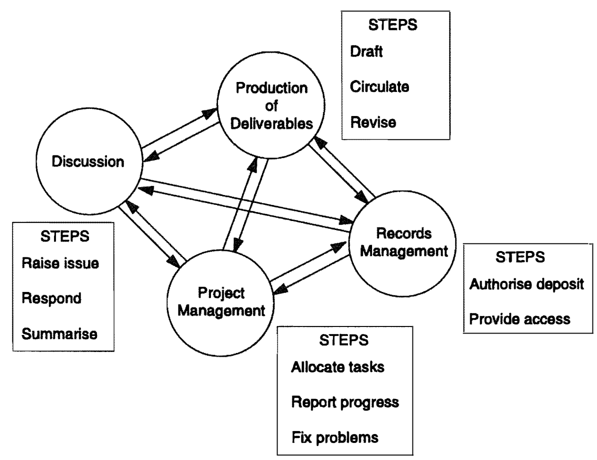

Figure 2. Activities in a group project.

Discussion

Discussions can range from brainstorming for ideas, to quite specific discussions on issues of content or style. Some management functions, e.g. definition of tasks, and task allocation, are likely to begin as discussions. A discussion may be characterised in the following way:

(1) somebody raises a question or issue for discussion

(2) other group members respond, e.g. by supplying ideas, further analysing the problem, or suggesting solutions, this process continuing (via responses to responses from all group members, including the

initiator of the discussion) until a process of resolution or exhaustion (of the topic or time) sets in

(3) somebody (perhaps the initiator) attempts to draw the discussion together by summarising the arguments and drawing conclusions, which may themselves reignite the discussion for another round (i.e. a return to step (2)).

In a formal group project, step (3) is very important, because the group as a whole must agree to (and "own") the conclusions from any discussion. Sometimes this process will happen automatically, but usually someone (such as the initiator) must be given or will take or negotiate the responsibility for seeing that this step is carried out. Some groupware products incorporate facilities (e.g. reporting and voting systems) to aid this process.

Production of Deliverables

The assumption here is that the overall task will be broken into a number of parts, each allocated to one member of the group. One group member may have more than one part. Exceptionally tricky parts may be allocated to more than one person to work on jointly, but even here, the responsibility will not lie with the whole group.

The activities involved can be characterised as follows:

(1) each group member develops their part of the deliverable

(2) the part is circulated to other group members for comment

(3) the document author then makes revisions based on those comment

(4) one group member then integrates the parts into a draft version of the final deliverable; steps 2, 3 and 4 may be repeated several times.

In this description, we have assumed that a single person (the author or integrator, depending on the stage) is responsible for revisions to the document. This is not always the case. Within the above scenario, responsibility for part or the whole of the final document may change hands at any time, e.g. for reasons of other work. A totally different scenario which must be supported involves a document being passed around a number of people, each of whom successively revises it. This is common when a document moves up an organisational hierarchy, being revised at each stage, or when one group member prepares a rough draft and hands it to another group member for further development.

Note that, during development of deliverables, discussions may arise regarding issues that come to light during that development, the conclusions of the discussion being incorporated into the final deliverable.

Records Management

For effective operation of the group there needs to be some sort of repository which acts as the long term organisational memory of the group. It often takes the form of a "project folder" in which any agreed standards, guidelines, design rationale and completed versions of work are kept. Work is lodged in the repository when it is seen by the group as in some way "complete", has been accepted by the group, and is no longer subject to frequent discussion and amendment. Documents in the repository may be replaced by later versions, but this is not a trivial process as it requires the group's acceptance of the changes.

Project Management

The management activities required for a project of this type are not complex, and do not need sophisticated techniques (e.g. PERT charts). However, they are a distinct process, and need to be identified as such. The activities involve:

- identification of tasks within the project
- allocation of these tasks to individuals (or subgroups) and the setting of deadlines for their completion
- monitoring of the progress of these tasks, to identify any problem areas, and taking corrective action (e.g. organising assistance) where needed.

As mentioned above, some of these activities are essentially discussions (or begin as discussions). Any management plan incorporates the conclusions from these discussions. For example, the tasks, how long they should take, who wants to perform them and who is best equipped to perform them, should all be the subject of discussion (and very likely, the same discussions that develop ideas and decide on content and structure). The management activity ensures that these issues are raised (and if necessary, raises them as a separate discussion), and records the conclusions of these discussions, i.e. what the tasks are, how long should they take, who will be doing them. Arranging meetings falls into this category.

Thus, the sort of information that is needed concerns the activities, who is responsible for them, their status (e.g. not started, completed, waiting on some other activity, in trouble) and expected time of completion (i.e. will it be late, and if so by how much). Where a person needs information or products from another person, this system can be used as a means of alerting the group to the existence of potential or actual problems in a timely fashion.

Private Conversations

No particular structure is postulated for private conversations. The major requirement is that they are in fact private (i.e. not accessible by anyone other than the participants), and that some means to conduct them exists.

2. A Possible Implementation

2.1. General

In the discussion above, a set of activities common to most group work has been identified. Different groups will conduct these activities in different ways, and place different emphases on the various aspects of them. For software support to be effective, it must allow maximum flexibility in the group's activities, while providing assistance where it is needed. Provided that the software is not too directive, the same software should be usable for both formal and informal group activities, for task-related and group cohesion activities, and for activities of sub-groups, the group as a whole, and for communication outside the group.

Our major interest is in designing and supplying support for students to contribute to group activities at times convenient to them, from work or home as well as from on-campus [8]. This indicates a groupware product which supports a different time/different place paradigm, and which can run on or be accessed through IBM-compatible and Apple Macintosh computers. Lotus Notes is a commercially available groupware product which meets these requirements.

2.2. Lotus Notes and the Design Task

The design task required for a Lotus Notes implementation is to build on the Notes infrastructure and provide group members with a conceptual model of how group work is supported so that they can undertake the formal and informal activities identified above as part of a typical group project.

We have designed a system with four sets of forms which present a conceptual model of group work to student group members, one set for each of the discussion, development of deliverables, project management and repository activities discussed above. Private conversations are supported by the e-mail facility within Lotus Notes.

As already mentioned, the process of summarising and drawing work to a conclusion has been left undefined. Unlike some group support systems which incorporate voting and other manners of closure, Lotus Notes has no conventions or processes for this. This designed boundary of groupware support allows and requires groups to negotiate work conventions and cues to draw activities to a close. Finding out how this is done, and whether it is appropriate to provide any explicit support for this, is part of the evaluation process for the project and is a question for further research.

3. Evaluation and Project Status

Initial use by a group of four students working from home has generated real interest in and enthusiasm for the project. An extensive evaluation with 50 students is currently being undertaken. The evaluation procedure addresses whether students use groupware support and if so, for what tasks and in what ways. Students are completing pre- and post- project questionnaires about their perceptions of groupware support and will also complete a set of structured diary pages to elaborate on their use of the technology during a critical part of their project work.

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Academic Risk-Taking and CSCL

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Abstract

Risk shift is a group consensus achieved through social interaction which tends to be more risky than the average decision of the individual members of the group. In the present study, the principle of risky shift was constructively applied to 137 elementary students working with a computerized mathematics task to increase their academic risk-taking behavior. Results of the study show that the observed risky shift in the educational situation was most likely caused by the problem-solving information shared among group members. It is proposed that an integration of risk-taking and computer supported collaborative learning environment will benefit students' learning and cognitive development.

Keywords — academic risk-taking, collaborative learning, drill-and-practice computer program, mathematics, modeling, self-efficacy.

1. Perspectives and Theoretical Framework

Psychologists have been explaining the risk shift phenomenon with several hypotheses. "Diffusion of responsibility" theory explains risky shift in terms of group members' feelings that in the case of failure, the entire group, rather than the individuals, will be blamed. "Value" theory contends that risk-taking is regarded as a valuable characteristic in American society; that group members tend to manifest a risky opinion as part of their cultural conditioning. "Familiarization" theory suggests that in a group, members have an opportunity to obtain more information about tasks, situation, and strategies, so they become bold in decision-making.

Guided by psychological theories and research, academic risk-taking has been demonstrated as a means to enhance students' learning and motivation. It has been postulated and demonstrated that moderate risk-taking maximizes satisfaction (Atkinson, 1957), enhances self-efficacy (Bandura, 1977, 1986), elicits constructive attributions (Meyer, Folkes, & Weiner, 1976), provides valued competence information (Trope, 1975), and ensures attention, concentration, persistence, and process-orientation (Csikszentmihalyi, 1990). Recent research has identified several task-related and individual difference variables, such as task objective, task criterion, task familiarity, payoff, and tolerance for failure, that affect risk-taking (Clifford, 1991). One variable that has not been explored is social environment of risk-taking, in particular a computer supported collaborative learning (CSCL) environment.

Social cognitive theorists contend that people can acquire knowledge, skills, strategies, beliefs, and attitudes by observing and imitating models (Bandura, 1977; Schunk & Gunn, 1985; Zimmerman & Ringle, 1981). They also demonstrated that both live models, who appear in person, and symbolic models, which are presented via instructions or audiovisual displays, are influential in observational learning. It can be expected that we can increase students' risk-taking by presenting a risk-taking model.

Another social environment variable is the social context of risk-taking, that is, whether the risks are taken individually or collaboratively. Based on research of risky shift (Harrell, 1991; Knowles, 1976; Turner & Cashdan, 1988; Wallach, Kogan, & Bem, 1964), it can be predicted that students will take higher risks in a collaborative risk-taking situation than in an individual risk-taking situation. This collaborative learning situation can be easily created and supported by using a computer as a learning tool.

General findings concerning the effectiveness of CSCL have been widely published. While King (1989) found no significant relationship between group ability level and success in a study of fourth graders engaged in computer-assisted problem solving, she did identify different patterns of verbal interactions between groups who were successful or unsuccessful in solving the problems. Hooper and Hannafin (1988) formed homogeneous or heterogeneous groups of low- and high-ability eighth grade students to complete a computer-assisted mathematics tutorial. Low-ability students in heterogeneous groups consistently outscored low-ability students in homogeneous groups. In a similar study with high- and average-ability fifth and sixth grade students, results indicated that students who worked in pairs learned more effectively than individuals across ability groups (Hooper, 1992).

However, none of previous studies investigating risk-taking or CSCL focused on increased risk-taking on school related tasks in a CSCL environment. If the principle of risky shift is applicable to students' academic risk-taking behavior in CSCL, it can be predicted that students will take higher risks in a collaborative risk-taking situation than they do in an individual risk-taking situation. It also seems that a drill and practice type of computer program would be a good tool to provide a CSCL environment for research where we can measure whether students will take higher risks in a cooperative situation or in an individual situation in order to solve problems.

In the present study, variables of modeling and social context were manipulated to examine the effects of these variables on students' risk-taking and the proposed explanations for risky shift in a CSCL environment using a drill and practice type of computer program.

2. Method and Data Source

Seventy-five third grade and 62 fourth grade students, 71 boys and 66 girls, participated in this study. Materials used in this study were (1) the Academic Risk-taking (ART) math computation task, programmed in HyperCard for Macintosh computers and (2) a questionnaire to assess students' feelings in the collaborative and individual risk-taking situations.

Students selected their own difficulty level to solve the problem in the ART program until they made 10 selections. Students' selections and performances were recorded by the computer to yield two dependent variables—difficulty and accuracy. The ART program also manipulated the modeling variable. A short story about a student's attitude toward risk-taking in academic situation was shown on the screen only to the students in the modeling condition. Subjects were randomly assigned to the modeling and non-modeling conditions. The variable of collaborative context was manipulated as a within-subject variable. In the collaborative situation, the subjects were instructed to work on the problems collaboratively and to reach the agreement on the answers before entering them. After the completion of the ART in each session, the questionnaire was administered. The questionnaire contained 12 statements on a 6-point Likert scale. The instrument yielded three scores: perceived responsibility, value of risk-taking, and familiarization of problem-solving. Data were collected in two sessions with a one week interval between the sessions.

3. Results

Difficulty scores in the individual and collaborative context were analyzed via a 3-way ANOVA with a within-subject variable of context and between-subject variables of modeling and grade. In addition to an expected main effect for grade (i.e., that 4th graders selected more difficult problems than 3rd graders), a significant context main effect was found, $F(1,133) = 13.47$, $p < .001$. As predicted from the risky shift research, students selected harder problems to work in the collaborative context ($\underline{M}$=4.31) than did they in the individual context ($\underline{M}$=3.88). For accuracy, the only significant effect found was the main effect of grade, $F(1,133) = 6.56$, $p < .01$, indicating third grade students selected problems resulting in lower accuracy than did the fourth grade students (means were 40 and 50, respectively)

Supporting the theories of "diffusion of responsibility" and "familiarization", subjects in the collaborative context felt less responsible for the risks they took ($\underline{M}$=3.18), $F(1,124) = 4.00$. $p < .045$, and obtained more information relevant to problem-solving ($\underline{M}$=2.33), $F(1,124) = 5.48$, $p < .021$, than they did in the individual context (means of 3.35 and 2.01 for perceived responsibility and familiarization, respectively).

4. Conclusion

Differing from previous research on risky shift where researchers focused on unhealthy behaviors such as shoplifting or gambling, this study applied the principle of risky shift in a constructive way to encourage students to select challenging tasks in their academic activities. Furthermore, this study provided explanations for risky shift in computer supported learning environment. Students in a computer supported collaborative risk-taking context tend to take higher risks because they feel less threatened by the consequences of failure, a finding consistent with research showing that students take high risks when external constraints are reduced. Also, students in the computer supported collaborative context took higher risks because they felt they gained information from each other by working as a collaborative learning group, a finding consistent with that in economics research that information reducing ambiguity increases risk-taking (Ellsberg, 1961).

Practically, this study shows an advantage of CSCL that has not been reported in previous research. Research has shown that collaborative learning is an effective method of increasing student achievement in various subjects and improve attitudes toward classmates and themselves (Sharan, 1980; Slavin, 1990;

Stevens, Madden, Slavin, & Farnish, 1986). Findings from this study suggest that collaborative learning should also be used as a means to encourage students to take risks in their academic tasks. Teachers and developers of collaborative learning projects should integrate opportunities to encourage risk-taking in the collaborative learning environment whenever possible. Also, as the familiarization factor suggests, teachers should encourage and enhance students' information exchange within collaborative learning environment, which will make them feel more comfortable with the problem space and more confident of their ability to solve problems. Computers are able to create this collaborative environment easily and appropriately without the presence of a teacher to provide immediate feedback. Using computers for drill and practice had an advantage of not delaying providing feedback on students' wrong answers until the next day, which usually happens in homework assignments. The computer's immediate feedback encouraged the students in the collaborative context to compare their solutions and discuss where the mistakes occurred, and even establish a peer coaching environment. The immediate positive reinforcement that the students who solved the problem correctly received seemed to encourage them to challenge themselves with a higher level of difficulty. Therefore, we believe that the integration of risk-taking opportunities into CSCL environments will benefit students' learning and cognitive development, although future research is needed to investigate this relationship.

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Shared Annotation for Cooperative Learning

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Abstract

CoNote is a system that enables a group of people to communicate via shared annotations on a set of electronic documents. The system is implemented using the World Wide Web, and operates with any standard Web browser supporting forms. This paper describes the conceptual model for collaboration in CoNote, and discusses our experiences using the system in an introductory college computer science course. We have found that shared annotations of documents provide a richer communications forum than electronic media such as newsgroups, bulletin boards and email distribution lists. The central difference is that the documents provide a context for discussions, thereby enabling people to find relevant information more easily.

Keywords — annotation, World-Wide Web.

1. Introduction

CoNote is a computer supported cooperative work system intended to facilitate communication within a work group through shared annotations (marginal notes) on a set of documents. The central idea is that shared annotations provide an effective communications forum for groups whose work involves frequent reference to some set of documents (e.g., teachers and students, field service workers, editors and publishers, standards organizations). In our experience, the shared annotations model provides a richer electronic forum than media such as news groups, bulletin boards or mailing lists. The key difference is that the documents being annotated provide a context for group discussions, thus enabling people to find discussions on particular topics more easily. The shared annotations model also provide a more structured forum than shared authoring tools, because the documents play the role of a fixed context for the discussions rather than being mutable themselves.

We have been experimenting with the CoNote shared annotation system since the fall of 1994, and have used it as the primary delivery vehicle for lecture notes and problem sets in Cornell's Computer Science 212 (CS212). We have found that students are able to easily locate relevant information because most of the dialog is in the form of questions and answers referring to a particular problem on an assignment. In particular, using CoNote we have rarely seen the same question being asked by different students, because they are able to find and understand other students' questions and answers. In this paper we describe the conceptual model for collaboration in CoNote and discuss our experiences using the system for teaching.

2. Overview of CoNote

CoNote is based on the World Wide Web, and is thus accessible to anyone with a Web browser supporting forms. No special client software is required, documents are read and annotations are viewed and posted using an ordinary browser such as MacWeb, Mosaic, or Netscape. Documents and their annotations may be written in plain ASCII text or in HTML. In contrast to other Web based annotation systems, such as Mosaic, CoNote annotations appear in-line at the place that they refer to rather than at the end of the document. Actually, only links to the annotations appear in the document; the annotations can be accessed by navigating this link structure. Numerous word processing systems permit annotations (e.g., Microsoft Word and Adobe Acrobat) but in such systems the annotations modify the document, and are not shared. In contrast, CoNote annotations are seen by all members of a work group. In the CoNote system, documents and users both belong to groups, which provides various levels of access control (as discussed in the following section).

Unlike paper annotations, CoNote annotations can't go just anywhere in a document, but only at places that the author of the document has designated

Problem 1

There are 7 annotations

Primitive Function returned from call to conference Student 1 Thu, 22 Sep 94 17:07:04 EDT

BUG IN ps3 SOURCE CODE?????? Student 1 Thu, 22 Sep 94 22:47:46 EDT

Defining cs-advisor TA Fri, 23 Sep 94 11:32:42 EDT

stategies Student 2 Sun, 25 Sep 94 16:45:39 EDT

BUG WITH POWERMAC Professor Sun, 25 Sep 94 18:43:03 EDT

My stupidity hasn't improved. Student 3 Mon, 26 Sep 94 17:42:19 EDT

Don't use ' Student 4 Mon, 26 Sep 94 18:16:30 EDT

You may add an annotation

Define an advisor named `cs-advisor` that uses some meaningful combination of the sample strategies we gave you in the code. Call the conference function with your `cs-advisor` and the `interactive-student`. For Problem 1, turn in the listing of your `cs-advisor` definition and a brief sample of the advisor working correctly.

Figure 1. How annotations appear within a document. The annotations list is delimited by horizontal rules. Note the tree structure: the second and third annotations are both replies to the first, and are indented accordingly.

as appropriate. We refer to each such place as an *annotation point*. When you are reading a document and reach an annotation point, you see links to all the existing annotations at that point. Each link shows the title (or subject) of the annotation, the name of the person who made it, and the date. The annotations at a given point are arranged into a tree, so that replies to a given annotation appear immediately below and indented with respect to it. Thus the structure of the display reflects the reply structure of the conversation.

An example of how an annotation point is displayed is shown in Figure 1. The original document being displayed contains the text above and below the two horizontal rules. The rules and the text between them are inserted by the CoNote system, because the author has specified an annotation point just after the text "Problem 1". There are a total of seven annotations at this annotation point, three of which annotate the document itself and the remainder of which are replies to other annotations. The first annotation has two replies to it, which are so indicated by indenting them one level (replies to replies would be further indented, and so on). The "smiley face" icon indicates annotations made by an author of the document; these are referred to as *authoritative* annotations.

The annotation titles are active links. Selecting a link displays the annotation in full. An annotation display shows the title, the name of the person posting the annotation, the date and the annotation text. Following the text are links to those annotations that refer to this one (if any) and those annotations that this one refers to (if any). This allows the reader to move through a conversation using information about the subject, author and date of each related annotation. Below the list of related annotations are three triangular navigation buttons, pointing left, upwards, and down. The left and right triangles take the reader to the chronologically previous and next annotation at that annotation point. Thus it is possible to follow the discussion at a given point in chronological order, rather than in terms of the tree which encodes the reply structure. The upward triangle returns the reader to the document itself, at the annotation point where the current conversation is rooted.

Users add annotations by filling out a form, specifying a subject and text. The date and name of the user are filled in automatically by the system. By default, annotations are entered in plain text, but people knowledgeable in HTML may enter HTML formatting codes if they wish. Each annotation point has a link to the form for adding an annotation, which is denoted by the link add an annotation. There is also a "Reply" button on each annotation. Annotations entered as replies are automatically linked to the annotation that they pertain to.

In addition to accessing annotations when reading or browsing documents, it is often useful to be able to search for annotation information according to attributes such as when the annotation was posted, what document it was posted on, who the authors were, etc. Thus there is a forms-based search interface that searches a given set of documents for annotations matching some query, and then displays a tree structure of just those annotations. The selected annotations can then be accessed in the normal fashion.

3. Conceptual Model

The CoNote model of the collaboration process is based on the concept of a **document group**, which is a set of people who share a collection of documents. Each person in a group has a certain **role** with respect to the documents in that group. The possible roles are **viewer**, **reader**, **user** and **author**, where each of these roles has more access to the documents than the one before. A viewer may view an annotated document, but can't see the annotations on it. A reader can also see the annotations, but can't add any. A user may read and add, and an author may read, add, and also delete annotations. In addition, annotations added by an author are considered authoritative and marked as such .

A person may have a different role in different groups. For example you might have the role of an author in one group and be a reader in another. Groups can also define a "default" role, providing some level of access to unregistered users. If there is no default role, then unregistered users are not permitted any access to the documents or annotations in the group.

Although annotations appear to the user in-line in the document, they are stored in a separate database, and are interpolated into the document when it is delivered to the user. Thus the document itself is not changed in any way by the annotations, and indeed it is usually stored read-only. This also means that the same document can appear in more than one document group, where each group has a disjoint set of annotations on the document.

A document group consists of a set of users, each with a specified role, and a set of documents. The set of users is specified by a **roles definition**, which lists each user and the role he or she has for that document group. The documents of the collection are each specified by a **document definition**, which names the document, lists the location in the file system where the text is stored, and may also list the locations of the annotation points within the document (see below).

Each document in CoNote has a unique name, the **docid**, which is a composite of the names of the document group and the document definition. Further, each annotation point has a name unique within the document. The author assigns these names when designating potential sites for annotation. Finally, annotations at a point are numbered chronologically.

4. Experience

We have used the CoNote system in Computer Science 212 (CS212), since the Fall of 1994. This class had about 90 students last semester, and has about 65 students this semester. All of the lecture notes, handouts and problem sets for the class are available on the CoNote Web server. The definitive versions of the problem sets are the online versions; that is, students are responsible for the information in the annotations, including any corrections or clarifications posted by course staff (document authors). This tends to focus activity on the online versions of problem sets, particularly as the due dates approach. For example, in the first 57 days of the current semester (from Jan 20, 1995 to March 17, 1995), 428 annotations have been made, and these have been read 7704 times. The distribution of the number of annotations read over time shows a strong correlation with the due dates of problem sets, as illustrated in Figure 2.

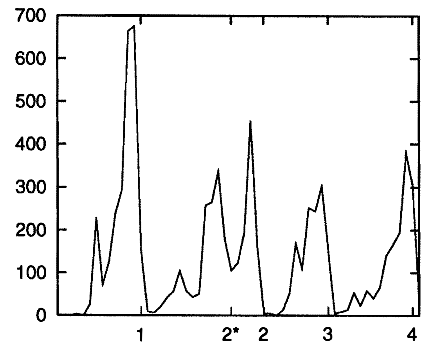

Figure 2. Annotations read per day by problem set due date. Note the double dip for problem set two, which was postponed.

The 73 users of the system have read an average of 105 annotations apiece in this two month time period. Some users read only a few, while a few read nearly all of them. Figure 3 shows the distribution of how many users read a given number of annotations.

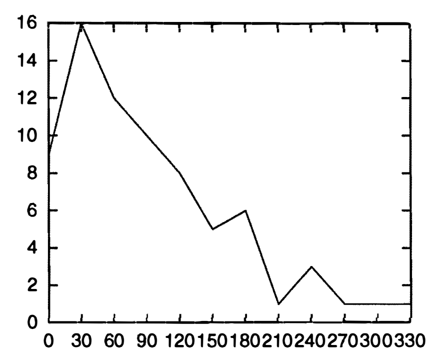

Figure 3. Number of users who read between *n* and *n+30* annotations. The peak (16) shows that most people read between 30 and 60 annotations, with the number falling off more or less linearly. Three users read 240 to 270 annotations.

In using CoNote, we have observed a number of interesting things. One of the authors (Huttenlocher) has taught CS212 for 6 years. The Fall 1994 semester, in which we used CoNote for the first time, had a considerably tighter grade distribution than in any other semester he has taught the course. In particular, there were many fewer students at the tail end of the grade distribution. Of course this could merely be random fluctuation, but there is anecdotal evidence that the shared annotations were particularly helpful to the students at the lower end of the grade curve. One of the main problems for such students is that they get stuck on the problem sets, which are large programming assignments. Often they fail to complete these assignments, which are nearly half of the grade in the course. This appeared to be much less prevalent. Moreover, several students commented in office hours that they found the annotations useful because it showed them that other students were also confused. Simply knowing that they were not alone seemed to make a big difference.

The annotations were clearly a part of the course materials, students often referred to annotations when asking questions in lectures, recitations or office hours. Students also developed high expectations about the turnaround time for having questions answered. They would often send email to course staff pointing out that they had an unanswered annotation from a few hours ago. Prior to the use of CoNote, it would have been unrealistic for them to expect answers in less than a day (as they would have to find a course consultant, TA, or the professor). It should be noted that many of the questions posted on the problem sets were answered (correctly) by other students. Thus, while the system did put an extra load on the course staff in terms of having to check for unanswered questions in a timely manner, it did not necessitate staff answering all of the questions.

Students used CoNote not just in the laboratory, but also from home (dormitories or off-campus). Table 1 shows the number of accesses to CoNote from various locations.

Table 1. Number of CoNote Accesses.

CS212 lab room	27,186
dormitory net	15,328
Cornell dialup	7,641
CS department	5,624
other Cornell	2,520
unknown or outside	146
total accesses	58,445

The course laboratory room was the most used site (about 46% of the accesses), but nearly 40% of the accesses came either from the dormitory network or the campus dialups (from students living off campus or in dorms not yet wired to the net). Approximately 25% of the dormitory rooms on campus have ethernet connections (the remainder will be activated this summer). Thus, we would expect that dorm access will increase further in the fall, as many students currently are not directly connected to the campus net.

A major role of CoNote has thus been to enable students to work as a group from their dorm rooms, rather than having to go to a special laboratory with many machines. It provided opportunities for "conversation" outside of the ordinary class- and lab-room locations. Many students listed this as a major advantage of CoNote on the course evaluation forms from last semester. Another advantage from the instructors' point of view is that CoNote provides all the students with the same access to information. When many students are working in the lab room, subgroups tend to share hints and information. Often these hints are wrong, and students can waste a lot of time as a result. The fact that the annotations are available to the entire class, and that both students and staff can correct misunderstandings, significantly improves on this.

5. Conclusions

Thus far, CoNote appears to be quite useful in teaching and learning. We have found that the shared annotations model enables people to find relevant discussions easily, by embedding the discussions in the context of a set of documents. The system is being actively used by students in CS212, and has become an integral part of the course. It is particularly encouraging to us that students have often been able to answer each other's questions.

We see a number of opportunities for further investigation. For instance, we could post each student's solutions after the due date, allowing students to compare their approach with that of others and to critique the style and format of other solutions. Just as in writing texts, there is much to be learned by reading and commenting on writings by other students. Second, we have a number of suggestions from the students to consider. One common request was the ability to delete one's own notes. We find a number of annotations are later followed by "oops" messages. Should these publicly visible mistakes be removed on the grounds that they are clutter, or should they remain, as encouraging evidence that even the best students (and even course staff) are sometimes confused? Third, we'd like to apply CoNote to other kinds of collaborations. In the teaching environment, there's a clear distinction between the authors (course staff) and users (students), in that authors are assumed to be authoritative. While this may be so in teaching, it is less likely true in other collaborative contexts. Fourth, we'd like to consider annotation of other media types besides text, e.g. graphics. Finally, we are working on a reimplementation of CoNote which will be both faster and more secure than the current version.

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Further information about CoNote can be found on the CoNote home page:

http://dri.cornell.edu/pub/davis/annotation.html.

Training Cops' Decisions in Deadly Force through Reflection by Use of a Powerful Learning Environment

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Abstract

The program *FireProf* is a demonstration of a computer based environment with the aim to support the thinking activities that foster flexible knowledge use of students instead of supporting reproduction of knowledge. It is an example of case-based instruction, situated learning in the workplace forcing cognitive collaborative knowledge negotiation, conceptual change and development. The paper aims to contribute to the discussion of how computer based programs can be used in education in another way as an electronic book or a game of putting the right answers forward to the posed questions.

The study concerns the training of 20 aspirant officers in justifying their judgemental shooting decisions in deadly force situations. Eight Officers interacted with an additional hypermedia learning environment Fire-Prof. No difference between experimental and control group could be determined concerning the progress in technical and judgemental shooting, and teachers judgements about students' approach (verbal, moving, tactic and decision). However the arguments put forward by the experimental group in justifying their decisions in deadly force situations increased in contrast to the control group.

Keywords — Hypermedia, constructivism, powerful learning environment, advanced problem solving, vocational training.

1. Introduction

Complex and rapid changes in society requires personal development, flexible knowledge, higher-order skills, social commitment and permanent professional education. This requires from learners an active knowledge construction instead of a solitaire information processing. Therefore education should not encourage learners to behave like Xerox copiers that mainly reproduce external knowledge. On the contrary, at any given point, education has to recognize that the learner has a store of knowledge about scientific topics that are his/her constructions of reality based upon his/her experiences or interactions with the real world (8). At any given moment this knowledge base has to be the starting point for future learning (14). Prior knowledge can enable the learner to relate concepts, to think of examples, to structure the learning material, etc. (12). In this way, adequate activation of prior knowledge (factual and strategic knowledge) can support knowledge (re)construction processes aimed at deeper understanding. By using prior knowledge learners can search for and construct meaning and structure (5) in order to act in complex problem situations.

At this point, we would like to stress that we do not consider the (re)construction of knowledge to be a goal in itself: we would like to plead for less rigid knowledge acquisition and maximizing the transfer of learned knowledge to real life situations. The ultimate goal of education should not only be students' graduation but the flexible appliance of '(school) knowledge' when *(a)* acquiring new knowledge and insight and *(b)* solving less familiar or advanced problems. Also when they finish school and learn and work in the community. Recent developments in cognitive educational psychology, instructional design and computer technology indicates promising theories and principles to meet these goals and requirements.

Constructivist notions (7, 3, 11) emphasize the subjectivistic character of knowledge construction as a result of students' individual knowledge and strategic experiences and their interpretations of the world around them. Also is emphasised that the acquisition of rigid factual knowledge is of less use when one never learns and practices how to use knowledge and strategies in complex intransparent situations. The latest are important to come to more understanding or to become able to solve more complex and unfamiliar problems. This has implications for the concepts and practice of learning and 'instruction' (6).

If a more structural understanding is required (e.g. creating a web of links between 'exact' knowledge, other domains, personal (pre)conceptions and personal interpretations of the world) instead of a functional understanding (e.g. able to answer questions; (2) then learning as a process of knowledge construction instead of a receptive or assimilative kind of learning but (10) is more adequate. It is the experience of the relativity of the heard, read or transmitted 'objective' knowledge, of construction of knowledge, of theory change that leads to students cognitive flexibility, which is needed to transfer formal knowledge in solving real-life, or new, advanced problems. Questions or problems for which mostly there is not just a single answer or solution. A reality where no single best way of thinking or knowledge exists, where the ability to question and evaluate the assumptions underlying various interpretations of the world in connection with the self-constructed knowledge is needed.

Educating for a less transparent reality addresses the instructional goal of forcing students awareness that multiple perspectives may be brought to bear on a problem (9); that coming to understand another's view requires dialogue, not simple absorption of what the other says or mere acquisition of new facts; that learning can and often should occur in social setting and negotiating (3). For designers and teachers it means a shift from the idea that learning should be situated in decontextualized and simplified contexts, towards the idea of learning in situations reflecting the complexity of reality.

Bringing an integrated form of hypertext/media and interactive multimedia in an instructional setting is often believed to stimulate students' active searching for and construction of meaning and structure by using foreknowledge and analogies. According to cognitive flexibility approach (11, 9) these kinds of integrated environments encourage the construction of knowledge if several conditions are met. They have to offer multiple representations forms (text, audio, visual, schematic etc.), multiple relations with foreknowledge by bridging, authentic and complex problems and 'random access' as well as stimulation of generative learning activities are incorporated.

But is it possible to assemble these theoretical notions into the learning practice of the workplace and does learning automatically takes place if these conditions are met? Many studies, however, show that only few students use their prior knowledge spontaneously and actively (1). Moreover, many students show the tendency to study for reproduction rather than for knowledge construction because they are not prepared and/or able to engage in cognitive and metacognitive activities aimed at constructing or restructuring knowledge (4).

Apparently, for many students instructional strategies and learning aids implemented in a powerful learning environment are needed to support that learners apply learning and thinking activities to accomplish knowledge (re)construction processes. Such instructional strategies and learning aids could be characterised as 'process-oriented': their aim is to ensure that students employ appropriate thinking activities in order to construct, change and use their conceptions of the learning content (13).

This study is an attempt to incorporate some of the above stated principles into a powerful learning environment. The subject of this environment is the training of police officers in taking and justifying split-second decisions in deadly force situations. The anticipation of policemen on possible deadly force situations was supported by stimulating their reflective thinking and argumentation. Therefore a case-based hypermedia learning environment (FireProf -PC-Windows-) was developed in which multiple representations forms (text, audio, visual, schematic etc.), multiple relations with foreknowledge, authentic and complex problems and 'random access' as well as stimulation of generative learning activities are incorporated. What is the impact of such an environment on the technical and judgement shooting skilfullness and the competence of justifying decisions and actions in deadly force situations.

2. Method

20 aspirant officers, students of the police academy, participated in the study. Students learning progress on life fire shooting, simulation shooting, approach and argumentation of their decision in simulated deadly force situations where registrated. The study followed a pre-treatment-posttest design. The treatment consisted of a regular four weeks shooting module. As pre- and posttest served the teachers judgement of students' behaviour (talking, pronunciation, moving, deciding, shooting) in a realistic simulated deadly force situation; students life fire shooting results, argumentation's of decisions in a deadly force situation, presented within a computer based measurement tool (decision and argumentation measurement, BAM). During the course use of the facilities in FireProf were on-line recorded.

During this module 8 of the students (experimental group)used FireProf, the hypermedia cases exploration program, and elaborated tree of the fifteen cases each. Besides the above mentioned data also on-line registration took place of frequency and time students used the different facilities in the FireProf program. The experimental students also followed, just as the other participants, the regular practical and theoretical lessons.

3. Material

Point of departure are the Dutch cases in the Fire Arms Training System (FATS: an interactive fire arm training simulation) and anticipation through reflective thinking on the split-second decisions in deadly force situations. The latest is done by stimulating generating learning activities like for instance requiring argument(s) of officers' decision, and by forcing negotiation of experience by require that students leave an advice or comment on the negotiation platform.

FireProf is a case exploration program offering multiple representation forms. Students have to take a decision and to act in an advanced realistic problem situation. The realistic, authentic, deadly force situation is presented on the monitor screen in a full motion software based video mode. By using the mouse a student is able to pull his gun and decide to shoot or not to shoot at a certain moment. The movie stops at that moment. After this action the student can counsel 7 different experts like for instance a judge, public prosecutor, colleague, a shooting teacher. They comment the students action related to his shot/decision moment. This is the way that the principle of 'cognitive landscape criss-crossing' is realized. Beside counselling this audio database the student can `criss-cross the landscape' by exploring the presented case by going back and forward picture by picture or to replay or play the digital video presented case forward. Each time a critical situation is passed other comments of the experts are available. The student can also counsel an indexed database of relevant subjects and law articles and an open database of 'cop rules' and cops' experiences. The latest is a realisation of the collaborative negotiation of knowledge platform. Because the students are unfamiliar with such kind of platform, they are forced to leave an advice or question for colleagues or teachers and other experts on the open database before leaving the program. There advice or questions have to be related to officers' approach in similar cases as presented. This action means that students build their own public knowledge base. Before ending the program the student is also forced to type in at least one argument why he decided to shoot or not to shoot. He also has to classify his argument as being a strategic, a law based or a social/emotional based argument

4. Results

4.1. Life fire shooting

A MANOVA was carried out on the life fire shooting data (accuracy fire and fire in self-defence). Although the experimental group showed a tendency of more skilfullness after two weeks of training this differences was not statistical significant. Both groups progressed in there skilfullness but no significant difference in life fire shooting could be determined.

4.2. Simulation shooting

The experimental group tended to hit more moving targets and showed better basic judgemental shooting results then the control group. However a MANOVA could not determine significant differences between the experimental and the control group on the pre- and posttest.

4.3. Teacher judgements

ANOVA's on the pre- and posttest data of teacher judgements of students' actions in video based, simulated deadly force situations could not reveal significant differences between the experimental and control group concerning students' verbal approach, moving, tactical approach and decision.

4.4. Argumentation and justification

Because of the small number of participants and the amount of argumentation categories no statistical analysis were carried out on these data. However the mean amount of arguments students used to justify their actions increased from 4,7 to 7.2 in the experimental group in contrast to a decrease in the control group from 5,3 to 4,7. The mean diversity of arguments decreased in the experimental group from 2,6 to 2,1 and increased in the control group from 1,9 to 2,2 different categories

The argument categories which the experimental group mostly put forward on the pretest concerned: `personal threat', `not shooting because of a hostage' and `alternative approach: calling'. On the posttest it concerned the categories: `personal threat', `self-defence (juridical argument)' , `subjective competence that it will be a hit' and `reconsidering the decision'. The argument categories which the control group mostly put forward on the pretest concerned: `personal threat', `not shooting because of a hostage' and `subjective competence that it will be a hit'. On the posttest it concerned the categories: `alternative approach: take cover', `reacting on what happens before' and `firearm suspected person'.

4.5. Use of facilities

Students mostly listened to the comments of the judge, the public prosecutor and the colleague with experience in a shooting incident. They also frequently made use of exploring the video based case by going forward or backwards. Students spent most of their time on formulating their arguments and reading, reacting on, or leaving a message on the negotiation platform

5. Conclusion and Discussion

The additional learning environment FireProf aims to stimulated students' reflections on and thinking through of split second decisions in the advanced problem situations of deadly threat situations. This had no effect on students' technical shooting skill, judgements of situations and approach of these situations. So, thinking through does certainly not has the effect that it inhibits people to react adequately. However it has an impact on the competence of students in using more arguments when justifying their approach and decisions.

Because of some hardware conflicts the experimental subjects could not use the FireProf-environment so intensive as was planned. Therefore the results has to be seen as a pilot study. The outcomes of an other study in which 70 police officers participated has to gain a better insight into the effectiveness and impact of a program like FireProf and also on the implementation problems of such a program in a working organisation.

The program FireProf is a demonstration of the possibility of a computer based environment design with the aim to support the thinking activities that foster flexible knowledge use of students instead of supporting reproduction of knowledge. It is an example of case-based instruction, situated learning in the workplace forcing cognitive collaborative knowledge negotiation, conceptual change and development. The results shows that multimedia computer environments can be function in an other way as an electronic book or a game of putting the right answers forward to the posed questions. Educational improvement is not served by designing a copy of a drilling, information sending teacher embedded in an attractive multimedia environment. The results shows that hyper or multimedia computer environments can improve education by functioning as a cognitive tool for the students to construct their own knowledge base in order to use knowledge instead of a drilling machine supporting copying and building a rigid knowledge base.

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Athena University — *VOU* and *GENII*: A Model of Conceptual Change and Collaboration

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Abstract

This paper has been written to describe what can be accomplished using the Internet to foster the development of resources, by people who live and work in diverse locations and educational environments. The goal of this project is to develop a seamless K to PhD educational institution that serves a sundry population seeking educational excellence.

The bringing together by a Consortium of Educators, the Group Exploring The National Information Infrastructure (GENII) and Athena - Virtual Online University (VOU), have combined with the Information Superhighway, to create a Virtual Educational Environmental (VEE) to provide an Online University, Teacher Training Center and experimental K-12 school. This Consortium is providing a platform that will become a Gateway to the World to bring home the World Community concept. We invite you to join us in this endeavour to make learning exciting and give, teachers and students alike, the ability to learn on their own and become researchers and collaborators in a World Community.

Keywords — Online university, distance education, K-12 teacher training, experimental K-12 Lab School, conceptual change, collaboration.

1. Introduction

The presentation of this paper is intended to document the potential of the Internet to foster collaboration and conceptual change between people who have never met face-to-face. Indeed, this paper is an example of the collaborative effort undertaken that would not have happened without the Internet technologies available. At this writing, none of the contributors have met in person. The collaborative effort to write this paper has been accomplished via the Internet, as have the development of the projects discussed herein. The distance involved spans over 15,000 miles and uncountable hours of effort to bring them to their current stage of development. All but a few of the people involved in the projects are either working or studying full-time; the others work full-time-and-then-some on the projects.

Despite the problems posed by distance, time zones, lack of resources and the varying levels of technical experience of the people involved, all the participants of the projects have gained a tremendous amount of knowledge about using, interactive online resources to collaborate with others working toward a common goal.

2. The Projects

During the months of April -June of 1994, two independent organizations established themselves as entities on the Internet. The first to make their presence known was GENII, an acronym for the Group Exploring the National Information Infrastructure followed by Virtual Online University (VOU) in June.

3. Their Missions

- GENII: To provide friendly, non-threatening assistance to K-12 teachers in gaining skills and confidence using the Internet.
- VOU: To establish an accredited Online University.

4. Project Development

GENII offers a helping hand: The GENII Project was established to facilitate the training of classroom teachers in skills necessary to use the latest digital communications protocols. The development team is a volunteer consortium made up of a very diverse group of educators and interested parents. They are in-service trainers, interested parents and teachers from all levels of education. This group agreed upon a common need and recognized that there was a way they could work together to fill that need. The purpose of the Project GENII team is to communicate, share and build on the work and experiences of everyone. They have agreed that there is a common need for the type of service offered and recognize that there is a way they can work together to fill that need.

GENII's mission was to establish a Virtual Faculty of networked educators to "be there" for the K-12 teacher learning the new skills associated with accessing the Internet. This Faculty will be an ongoing resource for teachers as they become more familiar with the workings of cyberspace and begin the process of learning and introducing tools and resources from the Internet into the classroom.

GENII has established:

(1) Gopher and World Wide Web (WWW) sites.

(2) A database of mentors; a list of names and CV's are available Via WWW and Gopher.

(3) Contact with The Amundsen-Scott South Pole Station, where a project was developed called 'The New South Polar Times'. This is an ongoing, first hand account of life at the South Pole, a biweekly newsletter written by one of the staff at the Amundsen-Scott South Pole Station, South Pole, Antarctica.

(4) A Warm Body Service for inservice training programs, by providing a real, first e-mail, contact to someone out there.

(5) A Pointer Service: As the Internet is so massive, finding sources that are appropriate for the K-12 classroom can be very time consuming. It is confusing to sort through the maze of information and then attempt to integrate it into the curriculum. GENII can help by giving them the benefit of our experience in locating resources and model how to best amalgamate them into the classroom.

The Internet Community has been built on a tradition of volunteer and helpful guidance. When someone makes an inquiry to a Newsgroup or to a Listserv, invariably several other users will provide answers, pointers or advice directed to that query. Often these responses will be thoughtful and extensive; well beyond what one would expect to experience in off-line life.

True to Internet tradition, the GENII Project has become a cooperative volunteer group of dedicated and knowledgeable individuals, who understand that training of teachers in the use of tools and resources of digital communications and data retrieval, is one of the most important outcomes that can be achieved if the National Information Infrastructure (NII) is to become something more than some 'giant digital shopping network'.

5. Higher Education with a Difference

VOU Inc. was incorporated in June of 1994, as a not-for-profit organization by the State of Missouri, with the intent to provide educational opportunities to a geographically dispersed population using the Internet. Immediately, VOU began to attract a core group of diverse individuals who felt that higher education, and education in general, was in need of general reform. VOU established as its mission:

To provide high-quality educational opportunities on the Internet as inexpensively as possible. It provides a forum in which students and teachers can pursue an integrated, interdisciplinary curriculum in the Liberal Arts. It is a medium for the free exchange of ideas in a non-physical setting, placing emphasis on ability and achievement. Critical thinking skills are encouraged and emphasized in an integrated and practical approach to Liberal Arts, rather than vocational education. As an equal opportunity institution it does not discriminate on grounds of ethnicity, creed, gender, age, sexual or political preference, nationality, economic status, or physical disability. Scholarly research and publishing is recognized as a necessary adjunct to quality teaching, but places priority on teaching and does not make research or publication a necessary condition of employment, job retention or promotion.

This has been accomplished by using an organizing structure along the lines of 12th century European universities with unions of faculty and students having minimal administration.

6. Conceptual Change

What makes VOU different from other universities? By existing in a virtual environment without the costs of maintaining a physical plant, VOU can offer a high-quality educational experience at a greatly reduced cost to the student.

Bill Painter and Robert Donnelly started with a vision for a new school house - one based completely on the Internet. VOU evolved from their interpretation of a mandate set forth by GNA and its Gold Curriculum Review Committee. What they proposed was the creation of an accredited Liberal Arts College set in virtual reality - A place where students would help create their own learning environment, work cooperatively in small groups, and explore their world via the global information superhighway.

In a few short weeks, Painter and Donnelly along with Dan Gerson designed and programed a text-based virtual educational environment known as Virtual Online University. The next task was to create learning tools and train instructors to use them effectively.

While teachers know how to use traditional tools like a chalkboard, overhead projector, to lecture, teaching online eliminates most of the cues good teachers use to monitor their student's progress. As instructors cannot see their students, in this environment, puzzled looks and even the simplest interaction filters through abstracted typed text. In such an environment, showing a student what to do takes time, typing, and very precise language. These do present some problems in the interaction between instructor and student but they are overcome in a short time. As the technology improves over the next few years this problem will soon be eliminated as audio and visual Internet links are developed and improved.

Regardless of the teaching environment, instructors generally use a lecture approach in-real-life and tend to deliver electronic lectures online. As this is a little more difficult to do in this environment, the first tools created or transported from other Moo's (Multi-user, Object Oriented environment) were the classroom, slide projector, notice board, and of course, the lecture. The lecture allows instructors to pre-load their thoughts, instructions, and communications and then deliver them line by line to their students.

In essence, the lecture epitomizes the paradigm shift required to restructure traditional education into a Virtual Educational Environment (VEE). The difference between the two can be compared to the evolution of automobiles from the horseless carriage to the modern car.

7. Advantages of Working in a VEE

Much like the horseless carriage, the 'lecture' approach to delivering instruction in a VEE tries to adapt a well known approach to a new technology with varying results. The lecture is very effective when instructors pause to allow a dialogue to develop and incorporate other teaching tools into it. The ability to access powerful tools such as the World Wide Web and Gopher browsers, simulations, tutorials, and most significantly, the VEE itself are a very compelling teaching device. The online browsers make gigabytes of information available to students, while tutorials and simulations can provide 24 hour a day access to detailed, information presentation, practice and feedback.

The VEE itself serves as a most important resource to students. It can be changed to respond to the requirements and desires of the learning community, by creating new spaces to match the curriculum and activities. Students can also add rooms and create objects to illustrate their conceptual understanding or to assist others in gaining such insight.

For example, a science student may create a demonstration and prepare a hypertext document relating their ideas to the theory. This becomes a portfolio of work for assessment. Traditional evaluation, if desirable, including multiple choice, fill in the blank, and matching exercises can be built with relative ease.

8. Disadvantages of Working in a VEE

Like most human creations, VEE's have their drawbacks. The current technology limits interpersonal interactions to text alone. Even worse, participation in the VEE depends on typing ability and knowledge of the English language. The command structure confuses even veteran MOOers, and the text output from players in the same location mixes together into a continuous stream of indecipherable babbling. Learning to survive in this demanding environment may take time, and not suit the tastes or learning styles of some people. The greatest limitation is the lack of good research into the niceties provided by interactive learning environments. Hopefully, in the near future, most of the disadvantages will vanish as the technology improves, where all that will be missing is the lack of face-to-face person-to-person interaction

9. Amalgamating Higher and K-12 Education

The concept of a Lab School attached to a University is not a new one. Many Teacher Colleges and Universities had Lab Schools attached to make the experience of a school setting, by student teachers, convenient for short term observation prior to them going into the field. In more recent times, with the escalating cost to maintain faculties, Colleges and Universities can no longer afford the luxuries of having a K-12 School close at hand. This however, is not the case with VOU and the GENII Lab School. The fundamental philosophies of both projects are to provide services to the learners and create a unique learning environment through cooperation.

As part of its research and testing phase VOU held its first Virtual Conference in the MOO in November of 1994. With presenters and participants from all over the world in attendance, the first Conference, 'Research and Pedagogy in Cyberspace: A Conferencing Workshop for Teachers On Using the Internet', due to the time zone differences, lasted an entire week. Most participants reported they had initial difficulties in adjusting to using the MOO but generally, evaluations were highly positive and each attendee expressed the desire to repeat the experience. Evaluations of the conference by participants supported the concept that MOO's were a great place to learn.

The GENII Project was invited to present a paper at this conference and George Duckett, representing GENII, made the presentation. It became clear GENII's own mission was entirely compatible with VOU's, though directed at teachers and students in the K-12 arena. As GENII was seeking a permanent base to establish itself as a viable entity, VOU offered GENII a permanent home for its Web pages and a site to use for conferencing. As the relationship grew it was realized that the two organizations had much to offer each other and collaborated in developing the concept of an Online Lab School. On the 18th of February 1995, The GENII project began an official relationship with Athena University - VOU by establishing the GENII Lab School (GLS).

Although now connected to a University, GENII's goal is still the same; to help organize the teacher's access to the Internet by first teaching the basic skills necessary to achieve a connection, then to provide a First Site for entry into the Internet jungle. Once inside, GENII's Virtual Faculty will be there to be the friendly, knowledgeable guide. Just conjure up a vision of the friendly genie from Aladdin's magic lamp and ride the Internet on his magic carpet.

Summary

There is currently little knowledge available of adult learning, micro worlds, distance education and instructional systems as they relate to online education. Thus, we try to adapt what is known to create the best learning environment possible, given our resources.

The best part of building a new technology involves testing the limits of the medium. We are heading towards a graphic user interface which will illustrate our VEE using brilliant pictures, icons, symbols and motion video with sound. The VEE will blend seamlessly with the World Wide Web, Gopher, E-mail, and video conferencing.

Students will be able to talk to their instructors, see their fellow students, and create their own version of reality using the graphic interface. While this may seem unrealistic and far-fetched, VOU has begun development of such a system. We intend to always test the limits of our medium, while delivering information-age technology and high quality instruction to our student clients.

Athena University - VOU and GLS uses a Multi-user, Object Oriented environment developed by Pavel Curtis at Xerox called a MOO. This environment allows interaction between faculty and students. Research has established that MOO environments have unique social characteristics which would facilitate a pedagogical format. VOU began to test this environment as a virtual classroom in September, 1994, by holding 'beta-test' classes. This period of examination was completed, and the consensus of both students and teachers is that it was a resounding success.

We consider the joint effort of all parties in the genesis and development of the University and Lab School, as a fascinating and successful model of conceptual change and collaboration. By using the tools and potential of digital communications, what began as a "What if..." scenario on the Internet mail list NII-TEACH, struck a nerve with a substantial number of educators and others who were obviously ready to take a proactive stance with regard to getting a seamless K to PhD community online.

The Staff Members of the online Athena University - VOU and the online GENII Lab School, extend to you a warm welcome and invite you to join them in the development of this new, exciting educational technology. We look to making a college education available to any person capable of haveing one by providing, a 24 hour 7 day a week service, accessible to persons normally unable to attend classes. In addition, offer assistance to the K-12 teaching community to develop the skills needed to use the Internet and related resources and provide a meeting place for them to exchange ideas and information.

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Design for Collaborative Learnability

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Abstract

This paper considers computer-based support for the development of computer skills in the workplace. We suggest that computer systems should be designed to support collaborative learnability; to this end, we offer a number of collaborative learnability design principles. In particular, we emphasize that the prime objective should be user participation. We suggest some principles of collaborative visibility and highlight the importance of the demonstration in the sharing of skills. The various design principles are incorporated into a generic model for collaborative user support called MutualAid. A specific system based on this model is also described. This system uses multimedia demonstrations recorded by end users to support an interactive problem-solving forum and the development of a local database of computer-related practice.

Keywords — Human-Computer Interaction (HCI), user support, learnability, collaborative support systems, collaborative learnability, collaborative visibility, multimedia demonstrations.

1. Introduction

This paper considers computer-based support for the development of *computer skills*[1] in the workplace. The focus on computer skills reflects both our background in Human-Computer Interaction (HCI) and our practical experience in helping people to develop these skills. Although some of our design ideas are particular to the development of computer skills, we see the fundamental basis of our approach as relevant to many other areas of learning in the workplace.

Our approach is based on a simple premise - the type of support of greatest value to computer users is knowledgeable assistance from their colleagues. We contend that user support should be designed to take advantage and to improve the quality of this mutual assistance. We have no hesitation in defining our work as *computer support for collaborative learning*. However, the fact that this learning occurs in the workplace, and not in an educational institution, has a profound influence on the nature of the collaborative learning and on the form of the computer support. As Koschmann et al. [11] remind us "... the presence of ill-structured problems in ill-structured domains is probably typical of most substantial attempts to use knowledge effectively in the real world. Well-structured knowledge domains and well-structured problems are almost exclusively the property of schooling" (p. 232).

Our research focuses on the *learnability* of computer systems or computer-based tools. We define learnability as *the properties of a (computer) system that aid in the learning of that system's use*. Any definition of learnability, however, depends ultimately on a definition of learning. We use the term *collaborative learnability* to emphasize a view of learnability based on a collaborative notion of learning. We are particularly interested in developing a number of generic design principles encompassing the essence of collaborative learnability. The various principles are incorporated into a generic model called *MutualAid*. We further illustrate our approach by describing a specific instance - MutualAid1 - of a *collaborative support system* developed from this basic model.

2. Information Technology in the Workplace

Information technology (IT) is playing an increasingly important role in most workplaces. In many cases an organization's productivity and capacity to innovate is closely linked to the IT proficiency of its workers, now transformed into end users. Although the typical computer system, such as a PC running a word-processing or spreadsheet package has become a rather mundane organizational artefact, it is still a powerful, complex

[1] We use the term computer skills to describe the expertise associated with the use of a wide range of software applications such as word processors and spreadsheets.

and multi-functional tool. Not surprisingly there are a growing number of reports of end users utilizing computer-based systems in restricted and simplistic ways (for example [4],[19]). We believe that these reports represent only the tip of the iceberg, and highlight a significant problem. We suggest that if we could improve the longitudinal learnability (support for learning over time) of computer-based tool systems this would contribute to better understanding amongst end users and hopefully lead to significant organizational productivity gains. We are aware, however, that there is more to expert practice than tool skills and that the design of the tool is only one factor in the many that can affect actual tool use.

3. The Theoretical Approach

In order to make anything more learnable we believe that one needs at least a working understanding of what it means to learn. Generally, support for the development of computer skills has been monopolized by formal instructional approaches, typically short training courses and self-instruction by way of printed documentation or on-line tutorials and help. The end user support task is normally interpreted as *the transfer of essential objective knowledge into the heads of individual users.*

While all forms of user support can play a part in the development of computer skills, we believe there are whole areas of understanding beyond the scope of formal instruction. These areas can be described as highly localized and situated ways of knowing organized around structures of relevance [18]. Designers of instructional courses and materials do not and cannot know these areas. Understanding completely the functionality of a tool (in the way that developers do) is nothing like understanding the situated application of that tool in workplace activities. Fortunately, in their efforts to come to terms with these areas of understanding the worker is rarely alone, he or she shares many of the situational factors with fellow workers. We see this as the basis for collaborative learning in the workplace. There is considerable evidence to support the proposition that *asking a colleague* is the most common and most valued form of support amongst computer users [6,7,19].

Although, some have speculated on the use of technology to support such mutual assistance (for example,[2]), generally, this approach has not received a great amount of serious research attention. Perhaps the prevailing belief amongst many is that this approach would be a case of "the blind leading the blind" or "computer-supported misinformation". A related area of research investigates organizational memory or know-how systems such as Answer Garden [1] and FISH [20]. However, these systems are generally text-based, organization-wide, involve universal structuring of information and do not make the collaboration process particularly visible.

We have been particularly influenced by ideas on *situated learning* [3] or *situated practice* [12]. We see the "situated argument" as an important contribution to the general process of recognition of mutual assistance as a valuable method of user support. Lave and Wenger [13] have suggested that the consideration of learning as "legitimate peripheral participation in communities of practice" can be a valuable analytical perspective. Most of the examples used by Lave and Wenger to illustrate their perspective are traditional systems operating in more or less stable environments. In many workplaces, however, mastery is in short supply and what is required is a kind of collaborative bootstrapping of expertise.

We use a number of basic working principles derived from theories of collaborative learning and situated activity:

- Learning in the workplace is primarily motivated by the everyday dilemmas and needs involved in work activities. Given the right conditions and the right support, these dilemmas can be turned into learning opportunities.
- What is of greatest value to the computer user is not "universal" instruction but access to and participation in knowledgeable situated practice.
- The fundamental operational unit of support is the small group. The mutual understanding and mutual commitment that can develop within these groups is a valuable resource in learning.
- Even with full collaboration local expertise may be limited. A group should always have ways of extending or improving its collective understanding by learning from the practice of others.

Our fundamental argument is that technological systems can and should be designed to support and to utlilize the potential for collaborative support.

4. The Social and Technical Basis of Support

Our approach is based on the notion of a sociotechnical system, in that it consists of a social sub-system and a technical sub-system. Both sub-systems are vital to the overall effectiveness of the system. As the sociotechnical movement found [15], if the technical system is optimized at the expense of the social sub-system the results obtained will be sub-optimal.

The fundamental social basis of support in our approach is the *support group* - a small, "closed" and hopefully cohesive group of ordinary computer users. This group should be engaged in similar or related work tasks involving the use of the same computer-based tools. Normally, this support group would be based on an existing work group. Within the support group an important role is that of the *support person* or local expert. The support person requires a combination of technical and social skills. They have to know in detail the tasks of the group, they need a knowledge of, or at least an interest in, computer systems, and they have to have a genuine commitment to assisting other members of the group in their various needs. Generally, a support person "emerges" from the group and is then sometimes recognized semi-formally by the organization. The importance of social factors in this kind of support system means that the success and effectiveness of the technical sub-system is crucially dependent on factors that cannot be directly addressed by technology. For example, the cohesiveness of the support group, the quality of the support person or the general organizational climate for learning can all have a significant influence on the success or failure of a collaborative support system.

Initially, we are interested in developing auxiliary systems that seek to facilitate collaborative support around *existing computer tools*. We believe, however, that ultimately collaborative support may be best served by integrating characteristics and functions that support collaboration within the design of the tools themselves. The growing number of computers connected to computer and telecommunication networks is providing opportunities for new and hopefully more successful approaches to user support. At present, most organizational end users can only be described as partially distributed. They still have the option of asking a question of a person sitting near them or of visiting someone nearby. In the future many workers may be part of a fully distributed organization where opportunities for face-to-face contact are extremely limited (for an illustration see Robertson [17]). In the partially distributed organization we believe that a collaborative support system can make a useful contribution to existing methods of formal and informal support. In a fully distributed organization such a system may be the only way to provide certain kinds of essential support.

5. Design for Collaborative Learnability

> *Jim: One section has produced a local procedures manual.*
>
> *Kylie: I don't see why we should have to write the manual for this section. We could do it, but we don't have the time to sit down and write all these things.*
>
> *Jim: What if someone comes to you with a problem?*
>
> *Kylie: But that's different, then they're asking you something and you're showing them. But to write it down - you don't know what they are going to ask. You would have to write down everything.*

The above section of a transcribed interview comes from a study we undertook into organizational end users and their methods of skill development [5]. We believe this very short section illustrates a number of crucial factors in the design of computer support for collaborative learning in the workplace. The comment "we don't have the time" highlights the principal learning constraint of the workplace - the amount of time and effort a worker is prepared do devote to learning. In collaborative user support we also have to consider how much time and effort a worker is prepared to actively devote to the learning of others. If we want people to use any kind of user support we have to minimize the amount of time and effort demanded of the user while maximizing the quality of the support provided. When Kylie says "I don't see why we should have to write the manual" we suggest that this is a reaction against the idea of manuals in general as well as the tedious chore of writing down all the relevant information. In contrast, the reaction towards helping someone is positive, because they have specific and personalized requests for assistance. It should also be noted that whereas Kylie uses the phrase "*writing* a manual" she refers to "*showing* them" when offering assistance. We feel this is an important distinction which we will touch on again later in the paper when considering the value of demonstration.

In summary, our aim is not to focus on the development of a database or manual of local practice, although such a database may be produced as a by-product of technologically-mediated support. The primary function of a collaborative support system is to provide technological support for local collaborative assistance or mutual aid. In the application of technology to this area we are not trying to undermine existing face-to-face support. We believe technology can make an important contribution to the collaborative learning process. At the heart of the process, however, it is still people helping people.

5.1. The Prime Objective is Participation

User support is essentially a discretionary function. In order to make an effective contribution to end user skill development a support system has to be more than just useful and usable - above all *it has to be used*. Our prime objective should always be to encourage use of the system and participation in its continuing development. To this end we have to be aware of the subtle constraints and inducements acting on the end user in the workplace. We do not think it is sufficient just to demonstrate that one type of user support is better than another by some form of contrived testing in an artificial environment. The real issue is not whether one example of user support is better than another but whether users will freely choose to use any example when not constrained by the test situation.

We want to extend the technology of the workplace to utilize and develop collaborative support. The driving force in the use and development of such a system is cooperation. Although cooperation is ubiquitous and intrinsically rewarding it is also a very fragile phenomenon. In the development of computer-mediated collaborative support systems what appears to be required is sensitive design and restrained use of technology. We suggest that a local and personalized focus on collaborative problem-solving appears to be a promising starting point for a collaborative support system. To facilitate this we need a method of local interaction between end users that provides a rich demonstration of possible problem solutions while requiring the minimum of end user time and effort.

5.2. Principles of collaborative visibility

In the study of Computer Supported Cooperative Work (CSCW), with its focus on the social processes involved in group interaction, there is a growing awareness of the significance of the "invisible" aspects of joint activities (see for example [8]). These invisible aspects are often vitally important habitual practices and other tacit understandings that people take for granted and are rarely aware of. Hutchins [9] has drawn attention to what he terms *open tools,* such as navigation charts. He suggests that the design of tools can affect their suitability for *joint use* or for *demonstration*. When a person is performing some activity the interaction between that person and a tool may or may not be open to others depending on the nature of the tool. Open tools provide opportunities for observation of tool use and may contribute to the general spread and development of more expert practice.

It has to be said, however, that desktop computers are not inherently open tools but instead are private tools - it is not easy to observe the interaction of a user and a computer other than in a very trivial way. In the workplace we start from a position where computer skills are largely invisible. Our goal is to make computer systems into open tools. To this end we have attempted to identify a number of generic *collaborative visibility* design principles. Collaborative visibility involves the revealing of both activity and the collaborative context:

(a) Make tool use visible

Making tool use visible to others is the fundamental objective in our quest for collaborative learnability. However, the idea of visibility goes far beyond the simple notion of being able to physically observe something. We believe that one of the most important methods of making tool skills visible is demonstration.

(b) Make the end-products of tool use visible.

Under certain circumstances the end products of tool use can be a quick and useful summary of what it is possible to do, in a given situation. They provide a kind of indirect visibility of activities.

(c) Support interactive discourse about tool use

Participation in the practice of a group is more than just the passive observation of someone doing something. Making something visible also involves revealing the meaning.

(d) Allow control of visibility

Control over the revelation of practice by the practitioner creates the opportunity for conditions of confidence and trust to develop and for practice to be revealed in meaningful ways.

(e) Allow capture and storage of examples of tool use

One of the inherent advantages of technological communication is that it creates the opportunity for the capture of interaction, thus extending visibility by making it possible to relay this information to other places or other times.

6. The Importance of Demonstration

Ask a colleague how to do something using a computer and they will invariably demonstrate it to you. You are invited into a position where the events occurring on the screen can be clearly seen, or the demonstrator takes over the controls of your computer. The demonstrator then goes through the relevant sequence of interactions between the user and machine. The significant events are emphasized usually by verbal commentary and you are also able to ask questions if a point is missed or needs clarifying. The demonstration, of course, has a long history. For example, it was an essential part of traditional apprenticeships. Recently there has been a certain amount of research interest in animated demonstrations as a method of instruction for computer skills (for example [10,16]). Some software packages now include animated demonstrations in guides to the system or as a part of on-line help.

The face to face demonstration can be a very important method of *communication between users* about the way to do things with tools. Demonstrations provide a special kind of visibility. They are not just a slice of everyday activity made visible, they have specific characteristics that make them useful for learning. A demonstration is *focussed* on a specific area, it is normally the answer to a query but could be an illustration of a problem or something similar. It is not just a randomly selected sequence of normal activities. A demonstration normally takes place under time constraints, therefore it tends to feature only events that are significant. It is a *condensed* version of significant events. The same sequence of events when performed during normal working conditions may have long time intervals between them. A demonstration is usually *interactive*. This interaction between the demonstrator and the learner is often very important. Interaction about the problem or the solution may change the whole direction of the demonstration. An active demonstration is also very useful for the demonstrator because it *aids recall* of the interaction between the user and the machine. Even experienced computer users find it hard to recall the sequences of interactions that occur between themselves and an application, when that particular application is not in front of them [14]. A demonstration normally also has a verbal *commentary* that serves to highlight significant events. A running commentary is not normally a feature of the average user's work activities.

Demonstrations can take many forms. We have concentrated on the face to face demonstration as the ideal model, but it has the significant disadvantage that this is usually only between two people and after the actual event the demonstration is lost. Technologically mediated demonstrations can be either synchronous, allowing real-time interaction, or asynchronous where a demonstration is recorded for later viewing. We can also envisage some kind of virtual reality demonstration taking place in cyberspace. At the other extreme most printed software tutorials incorporate static text and graphics demonstrations of how to interact with the system. We believe demonstrations are more effective in a situation where there is some measure of mutual understanding and mutual commitment along with shared or similar problems. This is the situation we have attempted to address with the MutualAid model.

7. Outline of the MutualAid Model

We use the term *collaborative support system* as a generic name to cover a whole range of possible technological systems designed to incorporate collaborative learnability. Our *MutualAid* model provides a generic basis for the development of specific systems utilizing different forms of technology. MutualAid1 (MA1) is one such system. It is a group-based asynchronous information sharing system focussed mainly on developing computer tool skills. This particular system utilizes recorded demonstrations as the principal means of communication and a collaborative forum and database to support discussion and subsequent storage of local knowledge. We emphasize that the MutualAid model is deliberately *minimal* and the MA1 system is a minimal prototype. There are a number of reasons for this minimalist design approach:

- The generic MutualAid model can be the basis for various systems utilizing a wide variety of representation, communication and storage forms. For example, we are currently investigating the feasibility of utilizing electronic mail, the World Wide Web and various groupware products as the basis for, or a part of, a MutualAid system.

- We feel that collaborative support systems ought to be developed collaboratively, if possible. We therefore consider our system as a minimal starting point for evolutionary development by participatory design contributions and contextual evaluation.

- Even when the system design has been developed and stabilized we hope that the form will still be considered as minimal. If users are having problems mastering computer-based tools the last thing needed is more technological complexities "thrown at them".

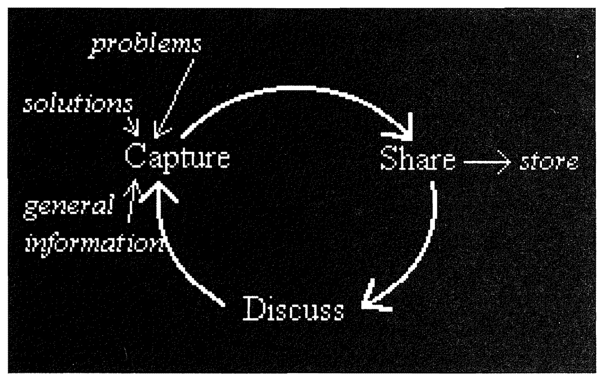

Figure 1. The basic MutualAid model.

7.1. The Conceptual Model

The basic conceptual MutualAid model is represented in (figure 1). It is as a cyclic process of capture, sharing and discussion. Problems, solutions, related experience and the discussion process itself are captured and made visible within a support group. The various contributions are stored for reference purposes. The driving force of the system is the collective resolution of everyday dilemmas (or innovative opportunities) associated with the use of complex tools in variable work activities, where time and quality are critical elements.

7.2. The Functional Model

The MutualAid1 system is a particular instance of a system based on the MutualAid generic model. Although this instance may be a valuable way to illustrate the general model we can derive many other specific instances from the basic model. The MutualAid1 system can be considered as three functional elements, the multimedia recorder tool, the problem-solving forum and a local database. The multimedia recorder tool is the principal method of capture in the system, although textual, graphical and other forms of representation can also be used. In order to facilitate the sharing of problems, solutions and general information and supporting the subsequent interactive discussion; we need some method of making these issues more visible or public within the support group. This is the function of the problem-solving forum. As a by-product of these processes a local database of practice is built up.

7.2.1. The multimedia recorder tool

Although it is possible to create textual and graphical descriptions of problems and solutions using the system, by far the most important method of communication is the recorded animated demonstration. There has been little if any published research into animated demonstrations *created by end users*. The recorder tool[2] allows the user to record an animated demonstration of screen events with a coordinated verbal commentary. The recording can be based on an individual demonstrating some aspect of tool use or it can be a recording of an interactive demonstration, that is, what we have termed a face to face demonstration between two people, with both sets of comments recorded. The interface to this tool is very simple, it looks and works in a similar way to the controls of a cassette recorder. The user selects record, demonstrates the relevant sequence of screen actions, while optionally making comments, and then selects stop. This creates a file, which can be played back to check the demonstration. The recording can then either be saved or wiped. Recorded demonstrations can be activated by loading them into the recorder or player and playing them. A simpler method of activating them is to embed them in a document as an icon using Microsoft Windows Object Linking and Embedding (OLE™). Recorded demonstrations can be embedded in a variety of document types. Documents with embedded demonstrations can be submitted to the forum or demonstrations can be added to existing documents already in the forum or database.

It should be emphasized that the users of this system are expected to be relatively inexperienced end users, we therefore want a method of operation that invites participation rather than adding to their learning burden. Perhaps the principal advantage of the recorded demonstration is that it can convey a great deal of information and yet is both easy and quick to create. We have found that a 30 second long recorded demonstration can convey a considerable amount of information and takes only a short time to record and embed in a document.

2 We saw the value of such a recorder tool, we then discovered Lotus ScreenCam™, an inexpensive multimedia screen and sound capture utility for Microsoft Windows™.

7.2.2. The problem-solving forum

The term forum (i.e., a place of public discussion) reflects both collective visibility and interactivity. The forum is the place where interaction, which is a vital part of the sharing and development of practice, takes place. It is also the way in which the local database grows and develops. Problems, solutions, experiences and general comments are made public within the group by inserting them as documents in the forum space, inviting responses from other members of the group. Responses to issues in the forum may take the form of new documents or may be additions to the original document. Recorded demonstrations can be added to existing documents very simply. To support the forum in Microsoft Windows we use a program group as a form of noticeboard on which documents can be posted. When discussion on an area in the forum has reached a reasonably stable state, the relevant responses are transferred (by the support person) to the permanent local database.

7.2.3. The local database

The local database is a collaboratively created collection of documents containing embedded multimedia demonstrations and other related pieces of information. Because it is locally created it can contain local methods of manipulating local information. For example, a part of the database devoted to using a spreadsheet can incorporate demonstrations of actions on the actual spreadsheet models used in the workplace. Initially, of course, the database is empty. It may be necessary for the support person (or the group as a whole) to submit a range of documents with embedded demonstrations covering the basic skills used by the group in order to achieve some initial "critical mass". The principal value of the database is that it provides a permanent record of local solutions to local problems which can be browsed or accessed quickly by members of the group. The demonstrations should be easy to access as a reference when someone needs to be reminded of the way to do something. Consequently speed and ease of access are important structural issues in the organization of the database. The central question in the organization of this local database is not how *we* should structure it, but what methods of structuring do we need to provide for the users.

We are currently testing this system in the introduction of spreadsheet software into an administrative department and also in a limited form in a course on computer skills for undergraduates.

8. Further Research

Just as a computer user may be isolated from the practice of others, a particular group of users may be isolated from the practice of other groups. There are obvious advantages in sharing solutions to common problems on a wider scale than the local support group.

However, various problems can be expected to arise when we attempt to communicate practice across group boundaries. Our intuitive approach to this problem has been to suggest a support persons' support group - a group where expertise can be developed at a more specialized level. The learning robustness of the support person or gatekeeper may be able to compensate for the initial lack of cohesion and understanding in the group. This intuitive approach requires further investigation.

The MutualAid system has been designed as an asynchronous system. This has technical and operational advantages, but there may be times when synchronous communication is essential. For example, problems may have to be resolved urgently or certain kinds of practice may only be able to be communicated interactively. We need to investigate the integration of a synchronous communication facility, paying close attention to the subtle constraints and inducements acting on its use.

9. Conclusions

This paper has discussed a collaborative approach to the problem of computer skill development in the workplace. We have presented a theoretical direction - design for collaborative learnability - and have illustrated this approach by outlining our MutualAid model and MA1 system. We have emphasized the central importance of demonstration and have utilized multimedia demonstrations as the principal form of representation in the system. We believe an approach based on principles of collaborative learnability and taking into account the potential of technologies such as computer-mediated communication and multimedia can transform individual computer-use dilemmas into collaborative learning opportunities.

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A Design for Effective Support of Inquiry and Collaboration

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Abstract

The Collaboratory Notebook is a shared hypermedia database designed to provide a scaffold for students as they learn to conduct collaborative, open-ended investigations. Through its structure, the software provides students with a genre for communication about scientific inquiry. In this paper, we examine the design goals for the Collaboratory Notebook in the context of an example of its use. We analyze Notebook use through student characteristics including gender, previous experience with technology, and attitudes and beliefs about science.

Keywords — educational groupware, collaborative hypermedia, inquiry-based learning.

1. Introduction

Student participation in collaborative, open-ended inquiry is a central goal of many current science education reform efforts. Collaborative inquiry is considered desirable, in part, because it reflects the authentic practice of science by scientists. However most students in high school science classes have little experience conducting open-ended investigations either alone or in groups. To provide a scaffold for students as they learn to conduct collaborative inquiry, we have developed a shared multimedia database application called the Collaboratory Notebook. The software has been designed with the explicit goal of supporting both collaboration and scientific inquiry. It has been created by the Learning Through Collaborative Visualization (CoVis) Project as part of an investigation into the use of advanced computing and networking technologies to support project-based science learning in a widely-distributed community of high school students, teachers and scientists [1, 2]

2. Genres of Inquiry

Studies in the sociology of science (e.g. [3, 4]) have shown that the medium of communication shared by the members of a scientific community greatly influences the development and maintenance of shared standards for work. Over time, the development of common structures for the presentation of research in the shared medium (that is, the genres of communication) serves the community by embodying, and subtly enforcing, its standards and values for research.

> *A genre consists of something beyond simple similarity of formal characteristics among a number of texts. A genre is a socially recognized, repeated strategy for achieving similar goals in situations socially perceived as being similar....The formal features that are shared by the corpus of texts in a genre...are the linguistic/symbolic solution to a problem in social interaction.* [4, p. 62].

As Bazerman[4] suggests, the standards of a genre can make an investigator's job easier by clarifying the way that a particular community will receive new work. This makes genres a potent instrument for instruction, and indeed the formal features of genres like research reports are often used for teaching. There is some reasonable doubt, however, as to the wisdom of "teaching" students genres, at least in the most didactic sense [5, 6].

No doubt, the process by which students acquire a written genre is a complex one, and this complexity is not due just to the need for them to acquire new vocabulary and to learn to put it together. Because composition is a form of social interaction, learning to compose within a genre is a process of socialization.

> *The student has to appropriate (or be appropriated by) a specialized discourse, and he has to do this as though he were easily and comfortably one with his audience, as though he were a member of the academy or an historian or an anthropologist or an economist; ...He must learn to speak our language. Or he must dare to speak it or to carry off the bluff, since speaking and writing will most certainly be required long before the skill is "learned." And this, understandably, causes problems.* [7, p. 135]

Of course, it is better if the student does not need to entirely bluff his or her way into a community. Having a valid mission, or a purpose for writing, helps. Our approach to the design and use of the Collaboratory Notebook reflects this thinking. In effect, the software embodies a genre that reflects sensible standards for investigation. When employed in the course of students' working on legitimate scientific problems, the Collaboratory Notebook is designed to support the acquisition of the genre of investigative writing.

3. Supporting Collaboration and Inquiry

In our development of the Collaboratory Notebook, we have sought to provide students with an electronic medium to support both inquiry and collaboration. The key to facilitating these scientific practices is the genre of communication embodied by the software. The software provides support for collaboration in the form of a networked database, accessible from anywhere on the Internet, in which individuals can share their ideas and actions with others.

The Collaboratory Notebook provides support for inquiry through a structured user-interface based on a task model of open-ended inquiry. Built loosely on the metaphor of a scientist's notebook, the Collaboratory Notebook allows a user or group of users to create a shared workspace called a *notebook*. Within a notebook users create pages that may be linked together through hypermedia links indicating the semantic relationships between them. Every page in a notebook is assigned a page type by its author(s). The page types, influenced by prior work, such as CSILE [8] and Project INQUIRE [9]. reflect a simple but flexible task model of scientific inquiry

The eight page types include questions, conjectures, evidence for, evidence against, plans, steps in plans, and commentaries. Pages may contain text alone, a graphic accompanied by text, or an "attached" document of any type. The hypermedia links enable users to connect pages together according to the relationships between them. For example, students may connect conjectures to the questions they respond to and evidence to conjectures they support or contradict. These page types and the links that may be used to connect them define the genre supported by the Collaboratory Notebook.

The genre defined by the page labels and links is designed to provide students with a framework for conducting and communicating about the inquiry process that encourages them to be systematic and reflective. The Collaboratory Notebook has been designed as a scaffold in the metaphorical sense, in that it provides students with a structure for their activities designed to reduce their need to focus on the challenges of organization so that they may focus more on the content of their activities.

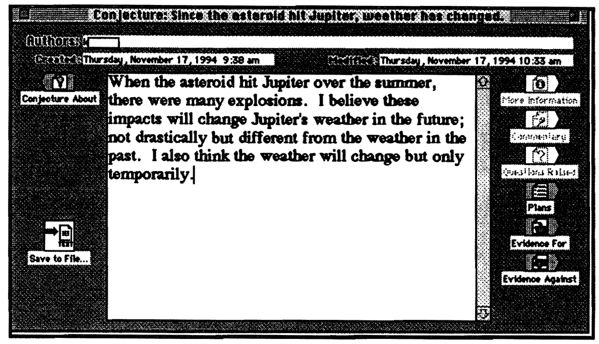

Figure 1. A Conjecture page. Links to other pages are represented by the buttons on the left and right side of the text.

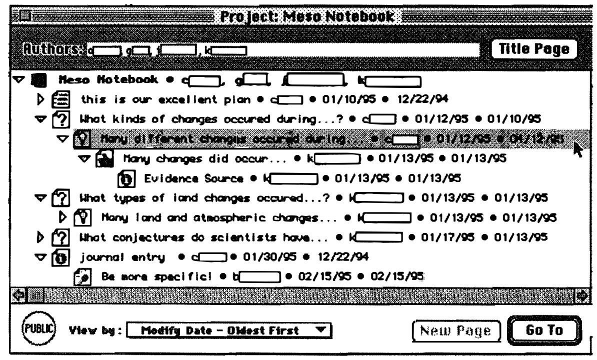

Figure 2. A notebook table of contents. Page types are indicated by icons; links are indicated by indentation.

In use, the page-types and the links play two additional important roles in scaffolding students' activities. The way the interface presents pages is designed to suggest appropriate next steps to the user. For example, when looking at a conjecture page, a user sees interface buttons that include those labeled *evidence for*, *evidence against*, and *plans*. These interface elements implicitly suggest to the user that he or she follow up the current conjecture with evidence relevant to the conjecture or a plan for acquiring that evidence. Second, the set of page and link types support the development of conventions within a community about the semantics of each page and link type. These conventions define a genre that provides both writers and readers with expectations about the relationships among pages and inquiry activities that ease the process of navigating through the hypermedia database—in sharp contrast to currently popular hypermedia environments such as the world-wide web and conferencing software that have links that are either untyped or customizable by individual users.

4. The Collaboratory Notebook in Use

The Collaboratory Notebook has been used to support a variety of activities by members of the CoVis community and others. In CoVis classrooms, the Notebook has been used as a facility for maintaining a record of students' thought processes and activities through extended investigations, as a forum for expressing and refining student research proposals, and as a medium for conducting community "knowledge building" [10] activities. Outside of the CoVis community, the Collaboratory Notebook has been used as a medium for sharing data and analyses from field work in an undergraduate ecology class, and as a supplement to in-person discussions in a medical school problem-based learning curriculum.

A primary characteristic of nearly all of these activities has been the role of the Collaboratory Notebook in allowing teachers to monitor and provide timely feedback on their students' work. In a small number of these activities, members of the scientific community outside the school have played a mentoring role, providing students with guidance and probing questions to assist the inquiry process. From a pedagogical standpoint, these uses of the software to monitor and guide students in the course of their work, indicate a role for the Collaboratory Notebook in supporting an increased attention to the students' process of learning as opposed to the traditional emphasis on final products. This form of collaboration where students and adults shape a students' work together stands in contrast to the conventional assessment dynamic where an adult simply evaluates students' work when it is completed.

5. A Study of Notebook Use

We turn now to an evaluation of the software's design. Elsewhere in these proceedings [11], we describe an activity conducted in a ninth grade classroom, in which students used the Collaboratory Notebook in the course of conducting open-ended research projects on climate. In this section, we present an analysis of those students' use of the Collaboratory Notebook in terms of user characteristicsthat designed to identify ways to make the software useful for more learners.

In our analysis we focus on three features of students' notebooks: their size, diversity, and linking. *Size* is a rough measurement of overall effort, measured by the number of pages and words contained in a complete notebook. *Diversity* is a measure of the number of different page types. *Linking* characterizes the connectedness of pages in clusters or trees. It is computed as the average number of links per page (branching factor), the average connected cluster size of linked pages, and the average depth of a page in a linked chain.

In the analysis that follows we use regression models to account for variability in the size, diversity, and linking in students' notebooks. The user characteristics we considered in these regression models were: (1) gender; (2) typing skills; (3) previous experience with computing for specific purposes; (4) writing apprehension; and (5) attitudes and beliefs towards science and science class. These data were collected through surveys administered in the first month of the school year.

We consider gender because there is evidence [12-14] that some applications, for instance, certain types of games, are appropriated by boys more readily than by girls. It was our hope that communication-centered applications like the Collaboratory Notebook would not be used differentially by boys and girls. Typing, and the use of specific computer applications, such as word processors and on-line services, were considered in order to examine the importance of prior experience and prerequisite skills. Finally, we assessed students writing apprehension in relation to their Notebook usage because of the possibility that discomfort with writing might reduce the size or number of pages written by students in their notebooks. We used The Writing Apprehension Test (WAT) [15], a measure that is designed to judge an individual's degree of comfort with written communication.

We developed regression equations for notebook size measured in total number of pages, diversity in use of page links, and the branching factor of Notebook pages respectively. Our strategy for developing regression equations was based on reliable, simple correlations between the dependent measures of notebook structure and use described above and independent measures of user characteristics. None of the other outcome measures we examined (i.e., words per page, average cluster size, average depth) had reliable simple correlation measures with the independent variables listed above. The regression equations accounted for variance (R^2) in the outcome measures in the range of ~12% to ~25%.

Notebook size. The regression equation for the number of total pages accounted for 22% of the variance. The only reliable coefficient in that equation was the use of on-line chat or discussion groups ($t(33)= 2.10$, $p < .05$) measured by responses to the question, "How much experience do you have using computers for using on-line chat or discussion groups?". We explain this result by the fact that students who have significant experience contributing to on-line interactive forums would feel more comfortable contributing to an on-line project notebook and would therefore be more prolific.

Diversity. The equation for diversity accounted for 25.4% of the variability in the number of page types that students used. Again, reported skill at using on-line chat or discussion groups was a reliable coefficient ($t(32) =2.42$, $p<.05$). In addition, students enjoyment of their science class was a reliable coefficient ($t(32)=2.34$, $p=.03$) measured by their answer to the question; "I enjoy classes in science." It would be reasonable to assume that students who enjoy science class in general are much more willing to explore the various features of the Notebook which are geared towards scientific inquiry.

Linking. The Branching Factor equation accounted for 12.7% of the variance in the number of links per page in students' notebooks. Here too, a measure of attitude toward science was the only reliable coefficient ($t(33) = 2.19$, $p < .05$) in the regression equation. In this case, answers to the question "I do very well in my science classes" were positively correlated with richer Notebook graph structure.

These results are interesting both for the correlations that were significant and those that weren't. Many of the user characteristics that could have significant implications for the design of the software or that have been shown to correlate with the use of computers or with performance in science classes failed to show significant correlations with measures of Notebook use. For example, gender, typing skills, use of word processors and other computer applications besides online interactive forums, and writing apprehension did not reliably predict any of the outcome measures of notebook size, diversity, or linking.

On the other hand, attitudes towards science and experience with on-line interactive applications did reliably predict notebook use. In particular, experience with on-line interactive software correlates positively with notebook size, which can be explained by these students' comfort with expressing themselves in a computer-based communications medium. In addition, positive attitudes about science correlate with students' use of the structural features of the notebook, i.e. diversity and linking. This can be explained by the fact that students who enjoy science and have been successful in previous science classes may be more accustomed to organizing their thoughts and activities according to the genre of scientific communication as embodied by the Collaboratory Notebook.

6. Conclusion

The Collaboratory Notebook has been designed to scaffold students as they learn to conduct open-ended inquiries in a collaborative context. In essence, it provides students with a genre for recording and communicating the scientific inquiry process. In the early analysis of use reported here, we observed that students with more positive attitudes about science and more experience using on-line communications media took better advantage of the features of the environment. However, many student characteristics that could have presented obstacles to use did not appear to do so. These early findings will pave the way for more in-depth studies of the effectiveness of the genre provided by the Collaboratory Notebook for supporting collaboration and inquiry among learners.

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Collaboration as Pedagogy, Collaboration as Window

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Abstract

Collaborative use of educational software may be thought of as a pedagogical means for provoking an intended conceptual change. When a collaborative situation makes team members dependent on each other's actions for success, their negotiations during problem solving ought also to provide a window into their reasoning. However, in work with young children none of this is straightforward. At first sight their collaboration may look like it creates more opportunities for misunderstanding than for learning, and their reasoning does not make the conceptual content very explicit.

A hermeneutic analysis which follows simultaneously the development of the varying perspectives from which the individual participants' understand the task, and the development of a joint approach to the task may provide a useful window into the learning process.

The paper presents some highlights from an example of this kind of hermeneutic analysis. The development of the interaction between two children playing a new game intended to promote a conception of "the system of numbers as a whole-to-parts system" illustrates how children may provide each other with learning experiences even in the midst of misunderstanding.

Keywords — Hermeneutic analysis, early arithmetic, educational software, classroom discourse, alignment of perspectives.

1. Introduction

In spite of frequent recommendations for group work with computers as superior over individual work it is still far from obvious how collaboration supports progress [7]. Collaborative problem solving is often used for pedagogical reasons with the goal of provoking conceptual change in students. It may also be thought of as a window into the conceptual foundations of the reasoning of the participants. When a collaborative situation makes team members dependent on each other's actions for success, their negotiations during problem solving ought to bring thinking out in the open, making it available for educational diagnosis or research purposes.

However, young children may not use explicit conceptual arguments in their collaboration, even in dealing with an arithmetic content where conceptual explanation would be the most powerful. Nevertheless, children in collaboration seem to be resources for mutually precipitating learning, even if this sometimes does not always agree with their intentions: when they try to share their knowledge they do not always succeed, but on the other hand they may provide each other with learning experiences even in the midst of mutual misunderstanding. Knowledge concerning these collaborative processes of learning is of great educational interest and value.

2. Conceptual Change and Collaboration

Conceptual change, in our view, is a phenomenon always taking place within the zone of proximal development [9], a zone of capacity for enhanced performance under adult guidance or in collaboration with peers. When developing educational software applying this concept, we have always admittetd the guiding role of the teacher. We thus agree with Rogoff [8] when she takes both guidance and participation in culturally valued activities as essential to children's cognitive development. As a consequence we have not designed our software to function in isolation from human intervention.

As our aim in the long run has been to produce games suitable for classroom use, peer collaboration is of focal interest to us. Actually peer collaboration carries a dual function in our studies. It exemplifies the classroom pedagogy we are aiming at, and it is our research tool for exploration of the processes of children's learning in interaction with our games. In both cases our pedagogic stance has been to minimize, but not totally withdraw adult guidance. Pedagogically we see learning through peer collaboration as promoting cognitive as well as social aspects of development.

Collaboration as a research instrument provides us with a window into children's joint reasoning.

This is not to say we try to open a window upon the mind in the sense of "an inner world of relatively stable and enduring cognitive representations" [1]. We do not study internal representations but, human *experiential relations to the world* [4, 5], and the window may be thought of as overlooking a jointly developed conceptual space, as it is structured from varying participant perspectives.

3. Hermeneutic Analysis

We suggest that one way to illuminate the dynamics of learning in collaborative computer use is the application of a fine-grained hermeneutic analysis to selected cases of collaborative interaction. Such an analysis proceeds by systematically exploring what each contribution to an ongoing interaction can tell us about the appearance of the shared space from the perspective of the contributor, as well as what it brings into the developing common space. This approach exploits for purposes of educational research the interplay and merging of horizons [2] that may further our ways of knowing in educational as well as in research situations.

This is not an attempt to "empathize" with the people subjected to inquiry. Nor is it an attempt to get into people's heads. Rather, it is an endeavour to listen carefully to what they have to tell us about the world from a certain perspective. We need to remember that this perspective is possibly different from ours, which does not mean that it will forever remain inacessible. Being prepared to grant a measure of reasonableness even to seemingly obscure remarks, we may follow them back to their point of origin and find the implicit assumptions embedded in that perspective on the topic under treatment.

4. An Example: Making Sense of The Rabbit's Game

As an example of this type of analysis we have used an interaction sequence from two first-grade children, Lisa and Kevin, playing an educational computer game by taking turns towards a common goal. The game was new to these two children, and it was intended to promote a conception of "the system of numbers as a whole-to-parts system" over a conception of "numbers as an object of step by step counting" [3, 6].

In the game in question, *The Rabbit's Game*, a sequence of completion problems (a+? = c) are presented in the form of a board game track. The track in the present example runs from 1 to 30. The numbered "stones" along the track are hidden at the start of each new game, and reappear one by one to provide the randomly generated subtasks, the goal being to make the Rabbit jump from his current position to the nearest stone visible further along the track.

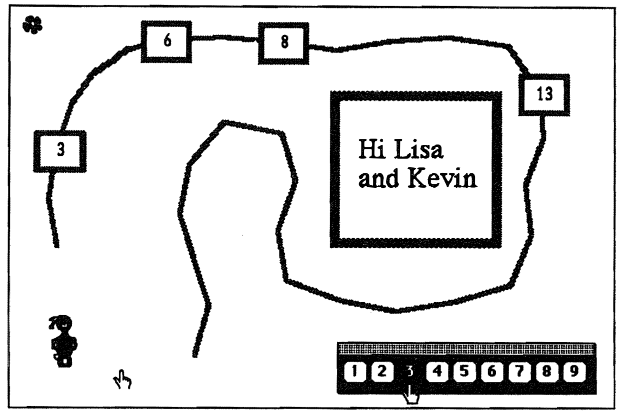

Figure 1. The Rabbit's Game, edited screen dump.

This game was very often initially perceived as being about *targeting and naming the endpoint* of the current leg of the journey, instead of (as intended) about *determining the number of steps in the next part* of the whole journey. The chosen case was found especially interesting as one of the children, Lisa, managed to hold on to the first and inappropriate understanding of the game for an uncommonly long period. In this way the processes by which this perspective is first maintained and then subverted are made more visible. However, due to restrictions of space we are not able to present here the full analysis of the twelve-minute sequence, but just a sample narrative.

4.1. The adventures of Lisa and Kevin

The children have no trouble getting to the stone appearing first, which is "number three." Then, however, in their attempts to get to "stone 6" they select first "7" and then "6" on the number panel. Each time the Rabbit bolts back to the beginning of the game. The third time they face the task of getting from "stone 3" to "stone 6" Kevin (prompted by the teacher to think of how it would work in a dice game) selects the correct numeral "3" to designate the three steps needed. Both children appreciate the success, but from what happens next it is obvious that they have seen its cause differently. Lisa still thinks the task is to name the target, whereas Kevin now adheres to the steps-in-a-part version.

The next stone to appear is "stone 8," the task is consequently to figure out how many Rabbit steps there are from "stone 6" to "stone 8." There is no discussion whatsoever of the appropriate number selection, no suspicion from either of the children of any divergence in perspectives. Kevin simply hands the mouse over to Lisa, who picks "8" on the number panel and clicks on the Rabbit without comment from Kevin. When she does, the Rabbit promptly bolts back to home base for the third time.

46K: Oh noohh! What's he going back for?
47L: Why, I **pressed** the eight!
48K: But you have to **press** on how many numbers there are in **between** here!

Both children are startled, although for different reasons. Lisa is offended by the game's rejection of the number that from her perspective is the unquestionably correct choice: targeting the endpoint. Kevin, who has taken it for granted that Lisa naturally would have chosen "2 steps" for getting from "stone 6" to "stone 8" is jolted into explaining his rationale. However, it is not transparent from Lisa's perspective that he is talking about a *chunk* of the track in his explanation. Although the episode seems to have rocked her faith somewhat, Kevin's explanation does not illuminate the step principle like a bolt of lightning and make her abandon the target principle she has embraced so far.

When the Rabbit is back in the same place again Lisa very cautiously accepts Kevins suggestion that she should select "2." It works, but she still turns to the teacher with a worried comment on the next situation, where the Rabbit has to go to "stone 13":

82L: (looking at the screen) That doesn't **work**.
83L: (turning to the teacher) He's got to have the one and the three now, doesn't he?

Selecting "13" will not work, as there is no single symbol for 13 on the panel, and no way to select two numerals simultaneously, either. At this point Lisa gets an explanation from the teacher:

84T: No he has to figure out how many steps you need to take to get from eight to thirteen...

Meanwhile Kevin has realised that a gap this size cannot be measured by approximation. He resorts to solving the problem on his fingers, counting-on in an audible whisper.

85K: **Yes, that's** it... *nine ten... nine ten... eleven twelve thirteen...* Now I know **exactly** what it is.

In this rapid series of events Lisa is first confronted with the inadequacy of the game to her perspective — or that it might even be her perspective that is inadequate to the game. She is provided with a formulation of the alternative perspective, and then, immediately, with Kevin's openly displayed invention of a working solution method for counting those "numbers in between." It is evident from her next move, that here the landscape from her perspective has at last changed into a problem of the current *part* of the whole journey.

She watches as Kevin selects "5." This successfully brings the Rabbit from "stone 8" to "stone 13," and produces the appearance of "stone 16" as the next problem for her to tackle. What she then says expresses in a minimal form her new understanding:

88K: See. Yeah!
89L: Oh, //**sixteen**... thirteen:n.
90K: //You can do it on your fingers. Fourteen fifteen sixteen...
91L: **Three**.

Lisa's observation of the situation is formulated differently this time. She notes not just where the Rabbit is going, as she has done before, but also what his current position is. She has finally realised that this is a pertinent aspect for solving the problem of calculating a part of the journey. In overlap with her assessment of the situation Kevin offers to share the method that he successfully used in the preceding turn. He demonstrates counting-up on the fingers as the way to figure out the correct number of steps. Lisa immediately gets the message, now that she has switched into a perspective on the task where this is relevant. She is the one to sum up Kevin's finger count and from now on they both use the finger counting method in all but the smallest jumps.

5. An Emerging Pattern of Interaction

The full analysis attends closely to the perspectival assumptions expressed in the utterances of each child in the unfolding chain of episodes. Here we can only comment on some features of the interaction between the children and its relation to their learning. It is notable that they do try to help each other with the problem solving, to share their understanding with the team partner. It is just as notable that they are not very skilled in detecting that they are speaking from discrepant perspectives.

There is, for example, a pattern of failure and remediation that occurs twice, once with Kevin positioned as responsible for the failure and once with Lisa in this position. In both cases the child who has not been directly responsible for the faulty selection first provides some kind of explanation. This is evidently expected by the explaining party to be obvious to the other child, who on the contrary manages to incorporate the explanation with his or her present perspective.

In both cases the "failing" child turns out to persist in his/her earlier preference, and in both cases the child who is in a position to see the other as responsible for a failure then leaves rational explanation and resorts to the persuasive force of her/his conviction as expressed in a repeated and emphatic offer of her/his own preferred choice — Lisa's happening to be based on a mistaken assumption and Kevin's on a correct one.

In both cases the child positioned as responsible for the latest failure then acts upon the strongly expressed advice of the other child.

Lastly, in both cases the child who has been responsible for a failure seems to be especially receptive to the more or less explicit hints provided by the teacher after having gone through the unsettling experience of first having their solution rejected by the computer, then receiving a more or less incomprehensible explanation from their peer, and then submitting – still without, comprehension – to a suggestion by the other child.

The pattern is suggestive of an interactional dynamics for a perspective switch on a local scale as an interplay between unsettling and supporting agents. Without unsettlement there would be no perceived need for a new idea. Without support there would most likely be desorientation instead of re-orientation.

6. Conclusion

By following closely the unfolding interaction between Lisa, Kevin, the teacher, and the computer game, considering at each step both the understanding making a specific contribution reasonable from the perspective of the individual, and its function in the interaction, we were able to study in detail how the "common space" of the actors was structured and re-structured throughout the sequence of episodes where first Kevin and then Lisa came to take the intended perspective on the game. Through Lisa's persistence in finding solutions in agreement with her perspective, we had an instructive highlighting of how a limited understanding is brought to the critical point where it can no longer be maintained. In this way the interaction between participants, despite being uneven and fraught with mismatches provided opportunities for learning.

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Towards Computer Support for Collaborative Learning at Work: Six Requirements

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Abstract

Instead of being an isolated activity reserved for classroom settings, learning is nowadays thought to be a central part of productive working activity. The growing use of information technology at work is a potential resource to support these - often collaborative - learning needs. However, it might be beneficial not to restrict support for collaborative learning at work to the same modes as in schools. To find out some suggestions how collaborative learning might be supported in working environments, some elements of learning are discussed and six requirements for learning support are identified.

Keywords — Workplace Learning, Collaborative Learning, Learning Support, Activity Theory.

1. Introduction

Until relatively recently, institutional education has been the main area where computers have been used for supporting learning while less attention has been paid to learning support at work. However, in the ongoing discussion about the new work and workers there is a demand to connect learning and working. As Zuboff [19, p. 395] argues, instead of being something separable from work, learning is crucial to productive activity: "Learning is no longer a separate activity that occurs either before one enters the workplace or in remote classroom settings. Nor is it an activity preserved for a managerial group. The behaviors that define learning and the behaviors that define being productive are one and the same. Learning is not something that requires time out from being engaged in productive activity; learning is the heart of productive activity. To put it simply, learning is the new form of labor."

Since learning has become an inseparable part of working, it should be supported also in the workplaces. The growing use of information technology at work is a potential resource to support learning at work. As Soloway et al [17, p.40] argue, "given that computers are being used for doing one's job, there is a clear opportunity to use those same computers supporting learning as one is engaged in ' doing' ".

There are already some ideas of how to support learning at work, but they usually assume that individuals are learning without collaboration. Since work is more and more carried out cooperatively (as the growing concern on CSCW applications shows), learning should not be an individual task, either. Studies on the learning of computer usage at work [e.g. 12, 1] show that computer users help other users to resolve problems and to make more effective use of such tools. However, Clement [7, p.23] notices that "there has been comparatively little work done to help users collaborate informally in learning to use the technology or in repairing interactional breakdowns when they occur."

However, it might be beneficial not to restrict support for collaborative learning at work to the same modes as in schools. The needs, constraints, and technological alternatives of learning support at work differ from those of school learning. Therefore, the purpose of this short study is to explore how collaborative learning might be supported especially in working environments. In this study collaborative learning is assumed to take place in the context of the emerging new form of work which requires understanding of overall processes, broad view of one's job, and local innovation to improve overall effectiveness [e.g. 15, 3]. In the next section some elements of the collaborative learning at work are discussed and six requirements for the learning support are identified.

2. Requirements for Computer Supported Collaborative Learning at Work

As a guideline in focusing the interest in this analysis is Activity theory and in particular the concept of activity and its general structure as suggested by Engeström [10]. All activities share the structure, learning as well as working. According to this structure an activity has an active subject, who understands the motive of the activity. This subject can be individual or collective. Furthermore, the actor uses tools (material or knowledge) to transfer the object of work. People participating in an activity are members of communities and their activity is cooperation according to the rules and the division of labour. These elements of collaborative learning and their requirements for support systems are next discussed in more detail.

2.1. Object

The traditional conception about learning at work is a continuum from novice to expert, where becoming good at various tasks requires gradual internalization of already invented knowledge and procedures. However, the context of working is in constant flux and "people regularly invent ways around difficulties, discontinuities and unexpected irregularities in the course of their daily work" [4]. To appreciate these local innovations implies second-order learning, which according to Ciborra and Schneider [8] involves being aware of the context of working and ways of doing things usually taken for granted. Similarly, Engeström [11] criticises the exclusive focus on internalization of the given and raises the question of generation of culturally novel models of practice. According to him [11, p. 17], becoming an expert is "learning what is not yet there" so that learning "becomes a venture of designing, implementing and internalizing the next developmental stage of the activity system itself". This, he argues, is a long-term and collective activity. Thus, the first requirement for a support system at work is that it should support creation of novel solutions and the improvement of work.

2.2. Tools

The tool of collaborative learning at work is the support system under scrutiny. The support systems at work usually include assumptions about the work and learning they are trying to support. However, these reasons for the tools being the way they are designed, start to disappear along with the development of the work while the support system remains the same. On the other hand, as work, its procedures, and its context develop in the course of time, they are left unsupported if the support system is not changed (see e.g. Bødker's [6] analysis on the tool used in Danish National Labour Inspection service). Therefore, learning support systems should be changeable in the course of time.

In addition, if workers are to invent ways around difficulties and unexpected irregularities, and learn what is not yet there as suggested previously, the computer support systems should be modifiable. It is not enough that the users are accompanying the designing process before it is implemented, they must have a possibility to redesign it all the time while working. Thus, the second requirement for collaborative learning support at work is that these support systems should be modifiable.

2.3. Subject

Focusing on the subject of learning at work raises the question about the notion of workers and learners. The traditional way of supporting learning at work has been implementing independent learning systems as in schools. Thus, people at work are thought to be either in the role of workers or in that of learners, only one of which should be supported by the system under scrutiny.

However, if work is not taken as a static situation but as a dynamic one requiring workers continuously to adapt themselves to circumstances and new working methods, it would mean continuous updating of two separated support systems, a system for working and a system for learning. If these systems are partly modified by their users as previously required, those people changing or increasing the knowledge in the learning support system might not be the ones who benefit of the update. As Grudin [13] has noticed, "application fails because it requires that some people do additional work while those people are *not* the ones who perceive a direct benefit from the use of the application." Therefore, a learning support system should not be a separated addition, but instead a central part of the work support system. This is the third requirement for learning support systems at work: a learning support system should be embedded in the working support system.

2.4. Community

The community of collaborative learning in schools is often a small group of learners, usually students in the group because learning is the main activity [as in 9, 16]. At work, however, working and learning are intermingled and it is recognised in recent CSCW research that collaboration does not require homogenous groups but collaboration is constituted by work processes that are related as to their content [2]. Thus, the learning community does not have to be a previously defined group of people, but instead it should be formed more or less around the working activity. This demand is furthermore supported by the study of Eveland et al [12], who found that the help providers were "sought out as much for their similarities to the help recipients in terms of work and position as for their technical qualifications" [p. 272]. Therefore, the network of helping relationships should follow in the first place work activity alignments rather than technical or pure subject matter specialization.

The learning community does not have to be previously fixed, however. The community of learning may also be in continuous change as the work and its context change. This requires that the learning community may be expanded when necessary and the support system should help in expanding the community. Thus, the fourth requirement is to support the construction of learning community around the work and to expand it.

2.5. Division of labor

The traditional assumption about learning in schools is the division of labour between students and teachers. There are supposed to be a teacher who knows the knowledge and students who are ignorant and need to learn. Similarly, the dichotomy between experts and novices at work assumes that experts have learned enough and it is the novices who have to learn. However, the distinction between those who know and those who do not know is not important [5, p. 172], because "expertise is a fluid, social construction that is constantly subject to redefinitions, the more so in times of rapid change".

Instead of using the separations between novices and experts, people should be considered both experts in their own practice (learning aspect) and the representatives of the requirements, the constraints, and the possibilities in their context of work (working aspect). They bring both this expertise and point of view into learning and the creation of new solutions. Therefore, the division of labor should be made according to this expertise and viewpoint in relation to the object of learning. This requires a support system that can be in the middle of a group of actors with divergent viewpoints and expertise. This requirement resembles the concept of boundary objects, which are according to Star and Griesemer [18, p.393],: "objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." Thus, the fifth requirement for collaborative learning at work is that the support system should be a boundary object.

2.6. Rules

Rules concern explicit and implicit norms, as well as conventions within a community. One common norm in school has usually been related to the assessment of learning. There has been the ultimate authority (namely the teacher) telling the correctness of actions and results. At work this kind of authority looses its meaning when people have to asses their doing and learning in the course of their daily work to be able to modify their work procedures and tasks. For instance, Howard [14, pp. 177-178] argues that "As work becomes more interdependent, a particular kind of skill becomes increasingly crucial to effective work performance. I call it 'organizational reflexivity', and by that I mean the capacity on the part of members of a work organization to systematically reflect upon their own organizational practice and to engage in the on-going modification of work procedures and tasks. Organizational reflexivity, in short, involves learning about an organization and its possibilities and knowing how to influence them."

This transition from an authority to self assessment and collective reflectivity requires that the learning support system should support critical reflecting and the going beyond the existing ways of working. Ciborra and Schneider [8] have also noticed this requirement and suggest that the tools "should support people's capabilities for reflection and inquiry within the context in which they are embedded." [p. 286). Thus, the last requirement for support systems is to support continuous and collective reflectivity at work.

2.7. Summary of requirements

This analysis has brought out six requirements for computer support for collaborative learning. These requirements are:

- it should be embedded in the working support system
- it should be a boundary object
- it should support the construction of learning community around the work and to expand it
- it should support creation of novel solutions and the improvement of work
- it should support continuous and collective reflectivity
- it should be modifiable

3. Conclusion

As learning is increasingly intermingled with working practices, learning support needs special attention in context of working environments. However, that is not to say that existing practices in school would not be useful - they have their own benefits and are needed - but the working environment may also need the support for its own special conditions to be optimal.

This paper has identified six special requirements for collaborative learning support at work. These requirements have two consequences on implementation. First, although there are some examples of how to fulfil some of these requirements at the same time, the real support system should integrate all the requirements into a coherent whole. Secondly, there are many possible ways to implement these requirements, and the chosen implementation should be derived from the work and the existing work support systems. Therefore, having one support system which could be brought everywhere is not possible as it is in schools. These consequences mean that there are still a lot of open issues to be solved and these requirements are only a context for further research and applications design.

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Team Learning through Computer Supported Collaborative Design

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Abstract

Colleges and universities have not traditionally educated their students in the benefits and techniques of collaboration. Rather traditional education has exalted the genius of the solitary scholar. Modern times demand otherwise of us, and educators must learn themselves how to teach collaboration. This is nowhere more evident than in the "design disciplines," those whose practitioners spend substantial portions of their professional lives designing things. These include engineers (mechanical, electrical, civil, software, etc.), architects, and writers.

This paper discusses the nature of collaboration in the design disciplines and describes innovations and studies in collaborative design education in which the authors are involved. A venue for collaborative design education and research is described as well.

Keywords — computers, networks and other technological developments relevant to CSCL, instructional strategies and approaches, instructional assessment issues.

1. Introduction

The modern workplace is dominated by collaborative activities. As products and services grow in complexity, collaborative work is becoming increasingly multidisciplinary. Consequently, educators must prepare their students for success in this mode of work.

This paper discusses how technology can usefully extend the collaboration process in face-to-face settings as well as prepare students for collaboration in the workplace. Also presented are reasons why current group decision support systems may not succeed in important areas such as design and collaboration education. An environment in which design teams can learn how to interact and succeed in their work is described.

2. Teams

A common practice in industry is to bring together people of multiple disciplines and expertises to achieve a common goal [Katzenbach91]. One of the greatest challenges in this setting is getting a group such as this to work together as a team. Each member brings his/her strengths (and weaknesses). The objective of the team approach is to develop solutions which are better than those any individual would likely produce.

"Team" is a familiar word and concept which has many interpretations. In this context, good teamwork results from listening and responding constructively to other's views, support and dedication to shared goals, and full participation. Good team characteristics also include shared leadership roles, individual and mutual accountability, collective work-products, and performance measures directly assessed from collective work-products. Members encourage open-ended discussion and active problem-solving meetings [Katzenbach91, Hutchins93].

To be successful, a team generally needs people who bring a varied expertises and who can fill a variety of roles --- organizing, evaluating, detailing, moderating, etc.

3. Traditional Meetings

Among all the events which occur during a team's work on a project, the most intensely collaborative and productive are often the team meetings. A meeting is a gathering of people with a purpose where communication among participants is the central activity.

Most meetings occur in an enclosed space with tables and chairs while the communication media are limited to verbal exchanges and visuals such as paper, overhead projection and video. Direct communication is largely limited to speech and the passing of documents.

As participants use the oral medium, the meaning of words and objects (sketches, charts, text, etc.) interweave to construct mutual understanding. If a team member is trying to explain how an engine works, for example, then the member may use photos, video, diagrams, graphs, and words to foster an understanding for others. Others in the team may use the spoken word and the other representations to query the expert on how the engine works and the terminology which describes it. Without clear communications, the team may spend hours needlessly debating before they recognize and correct a simple misunderstanding.

During a design project, a team travels through an abstract domain of ideas in which they collect, compare, join, discard, revise, etc. The path taken includes many decisions made along the way, and a group may use many decision making methods during the design process.

When a decision is made by consensus, all members usually understand the decision and are prepared to support it. In practice, consensus means that all members can rephrase the decision to show that they understand it, that all members have had a chance to tell the group how they feel about the decision, and that those members who continue to disagree or have doubts are nevertheless willing to give the decision a try.

Throughout the process, the design team tries to attain a mutual understanding of issues and solutions. When a group has a mutual understanding, they are able to move to consensus on a point.

The construction of a mutual understanding through dialogue includes both agreement and disagreement. [Burnett93] found a significant positive correlation between the amount of substantive conflict during invention and the final product quality. Substantive conflict appears to allow participants to fully explore the possible alternative courses of action.

4. Face-to-Face Meetings

Problems in traditional meetings include ideas that do not surface and are lost, time wasted on "political posturing," the serial nature of communications (i.e., discussions of one topic at a time), and documenting the meeting [Dallavalle92]. In recent years meeting rooms have incorporated telephones and television in order to permit live communication with distant conferees and for showing pre-recorded material (essentially "hard copy"). Computers have also been added to gather, organize and distribute information.

Distance collaboration offers obvious advantages but suffers from bandwidth limitations of current communications technology. To explore the ultimate promise of coming technology and to address directly opportunities present in most on-campus college settings, we consider face-to-face meetings.

5. Media in Meetings

Multiple media give individuals many ways to express their ideas in written documents, notes, sketches, graphs, tables, audio and video recordings, etc. A variety of formats allows others to view an idea from many viewpoints, increasing each person's chance of gaining an accurate understanding.

For example, the floor plan of a house gives no direct sense of vertical dimension. However, two drawings or a perspective drawing can make it possible to comprehend the third dimension. A dynamic onscreen walkthrough is even better. On the other hand, graphical instructions on assembling a bike without any text would be of little use. Words are generally helpful in describing how to make parts fit together. In a third example, the weatherman may say it is "cold" outside. For someone in southern California, "cold" may be 50 degrees while someone in upstate New York might define "cold" as 20 degrees. Without the numerical representation for the temperature, the meaning of "cold" is ambiguous.

In a collaborative design session, there may be other options for expressing ideas. When an idea is introduced, it may be rendered in multiple forms thereby increasing the chance of its being understood. Different ideas generally benefit from expression in different media, each medium chosen to best convey an aspect of the idea at hand. Furthermore, modern electronic communication can bring appropriate information from a myriad of sources in various media to a team. This access to global information resources prevents unnecessary delays and delivers information when it is most valuable and usable.

Good multiple media will free people to think associatively and attach comments to the ideas being presented. Team progress and reports may be thus built automatically during deliberation. Appropriate tools may also encourage multitasking in the sense of a person concentrating on the current topic without forgetting what s/he wants to say (whether or not that topic has passed).

When multiple sources of information compete for our attention, cognitive issues are raised. For example, most people are able to listen closely to one speaker yet give enough attention to others to permit them to detect enough content to earn a shift of attention.

The use of multiple media raises further cognitive issues. For example, the confusion present when multiple sources communicate within a single medium may be reduced when the sources are spread among several media. Multiple media sources may affect the level of interest generated and may serve either to stimulate or distract participants. The sequencing of information may be easier when alternate media provide alternate channels for acknowledgment of receipt.

Over the past 10-15 years various academic and commercial organizations have built and used computer-supported group decision support facilities

[Nunamaker93, Marca92, McLeod92, DiPietro92]. These have incorporated networked personal computers running group decision support software (GDSS) which coordinates idea generation, evaluation and decision making [Stefik87].

Because most GDSS designs emphasize information management instead of collaboration support, these traditional decision-support systems are not consistently effective in meetings [Marca92]. Many GDSSs are highly structured and have tight synchronization points. The computers are a central part of the meeting and force the group to follow a meeting script dictated by the software. A professional facilitator may be required for each meeting. These systems generally do not foster learning of group dynamics and how to interact but instead simply follow a model decision process algorithmically.

Thus GDSSs seem to assume that teams cannot succeed by themselves forcing control structures on the team. The ideal system would not assume this; it would be flexible and allow people to share ideas and information with a less enforced structure. Users would be empowered by the technology.

6. Collaborative Learning Through Design

To be productive in design meetings, the participants must be familiar with roles, activities, and protocols which are all part of meetings. Training sessions must familiarize participants with meeting roles such as those described by [Pfeiffer91] and with meeting activities such as generating ideas, negotiating, assigning action items, reviewing existing items, and presenting.

A group "history" should be established through team building. Introduction of an electronic meeting system into an ad hoc group project with little or no group history tends to increase the degree of apprehension about meeting and about communications media [Chidambaram93].

The Rensselaer Design Conference Room (DCR) has been created with these things in mind. The DCR is a conference-sized room accommodating 6 to 10 people. Participants generally come to this room with their individual ideas, information, documents and visuals ready to present or otherwise inject into a team discussion. The DCR has access to all network services.

The physical configuration of a DCR conference is sketched in Figure 1. The table has a central hexagonal portion containing "public" screens (large color monitors) in front of each pair of team members. Three wings extend from alternate edges of the central hexagon. Each wing houses two workstations for the use of individual team members. All screens are buried below eye level so as not to impede visibility and dialog among team members. This table design gives each participant a private workspace as well as access to the DCR Collaboration Network (CN).

Participants are able to take and cede control of the "public" workspace via protocols administered by this software. They are able to move items back and forth between public and private screens in the course of a meet- ing. This electronic activity is complemented by active oral dialog with significant synergy.

The Collaboration Network is viewed as *hyper-group-ware*; that is, a framework into which applications soft-ware, both single user and groupware, can profitably be imported for joint use.

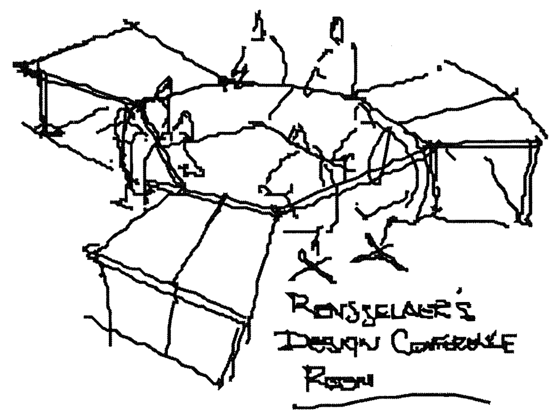

Figure 1. Sketch of DCR table configuration.

A form of anonymity in this face-to-face setting is available via a "chat" program. Anonymity may reduce apprehension and increase focus on ideas, yet in the DCR, everyone still has the advantage of a full range of visual and oral cues. For each project, there is storage space for team and individual files. A teams can form sub-projects which arehandled hierarchically within a main project.

The main CN interface is shown in Figure 2. It uses a schematic table top to show all participants in their posi -tions around the DCR conference table. There are three participants in this specific collaboration session, as indi- cated by the shading of their heads. Each has an appropriately oriented copy of this table on his/her private screen. Anne is in control of the public screen, and Cheryl has requested control. The person in control can drag her cursor smoothly from her private screen to the public screen and back again, shifting both mouse and keyboard control between computers. Moreover, the clipboard fol- lows silently, carrying data between domains. To support active give and take, a user not in control of the public screen can drag her/his cursor onto the public screen where it turns into a personalized "ghost" cursor to serve as a pointer during discussion. The buttons in the center allow a user to interrupt ("!") or freeze ("stop sign") the control of the public screen. These media sharing/control protocols evolve as we learn more about better meeting support mechanisms.

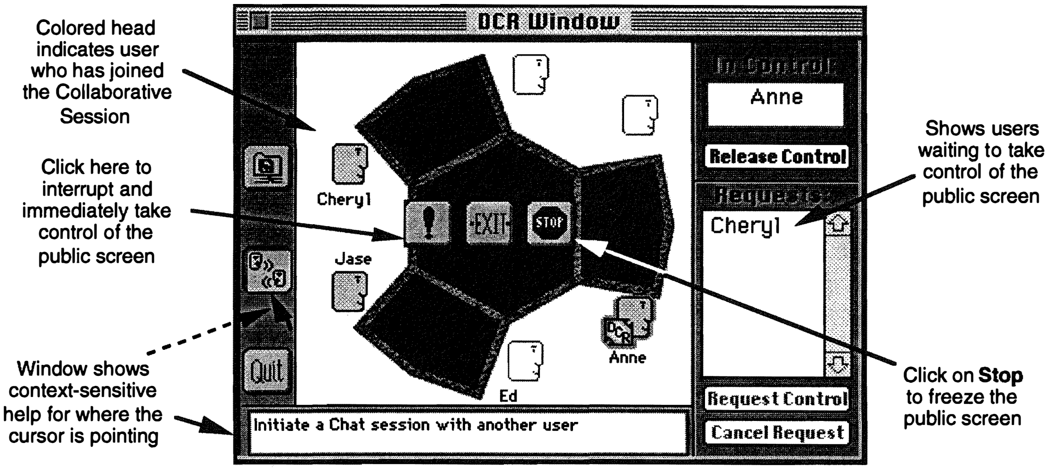

Figure 2. CN interface window during a collaboration.

In the DCR environment, the group focus hovers across the conference table. Since the public screens are in the table (and not projected on a wall), electronic information is more like paper on the table. Team members can transfer their attention between teammates and other forms of information with minimal physical movement. This arrangement alters what would tend to be a presentation in a traditional meeting to a group discussion.

Students who have not taken part in teamwork before may be apprehensive. However, a brief training session and the synergy of multiple media, used with effective protocols, overcomes this. The ability to control media through various well-defined protocols gives each team member greater opportunity to be "heard," spawns creativity, increases mutual understanding, and results in a greater sense of team ownership.

7. A Study of DCR and NonDCR Teams

Data on two undergraduate teams working on the same projects for the same course (Software Design & Documentation, Spring 1995) have been gathered and are being analyzed. One team used the DCR, the other did not. Baseline studies of teams from this course and from Rensselaer's Design of Mechanical Systems course have been conducted since 1991. Future studies will include multidisciplinary teams of engineers, architects, managers, and technical writers.

The general research approach is to make observations of progress on projects and processes used by a team. Due to the complexity of design team behavior over time, several methods are used to gather data. Each week activity logs are collected from each student. Logs describe the work they have done in relation to the assigned projects, including individual, subgroup, and team work. An observer attends, takes notes, and tape records each team meeting. In a DCR session, an event log (including occasional public screen dumps) is also kept automatically. The team observer conducts team member interviews and each member assesses team and co-worker performance twice.

Transcripts from all sources must be synchronized so that critical transitions in team thinking and behavior can be identified. The number of issues discussed, ideas generated, topical shifts in discussions, participation levels of group members, the amount of time spent discussing topics, the quality of the design process, and the quality of the final design are measured.

A second phase of the research is a study of how protocols for media resource control affect team behavior and work product. Due to the unpredictability of how team members will interact at any given meeting, the protocols, whether formal or informal, must be flexible. The ability to adapt protocols for the task at hand should increase the effectiveness of communication.

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Distributed Cognition, Learning Webs, and Domain-Oriented Design Environments

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Abstract

The human mind is limited, making collaboration with other humans and with things (in our case with computational environments) a necessity rather than a luxury. Relevant knowledge for work and for learning is distributed in our head, in the heads of others, and in the environment.

Learning webs are used by (virtual) communities of practice. Domain-oriented design environments (DODEs) support learning webs by allowing all stakeholders in a design process to learn and work collaboratively with each other and with their computational environments. DODEs serve as models for the design of collaborative working and learning environments by exploring and supporting different relationships and task responsibilities between humans and computers.

DODEs integrate working and learning by grounding learning in self-directed, authentic activities. They support learning on demand as an essential element of life-long learning. The creation of DODEs faces the fundamental challenge to make them simultaneously learner-directed and supportive. DODEs transcend other computer-supported cooperative learning systems, which employ the computer only as a medium with few interpretable components. They integrate humans and computational resources more creatively by acknowledging that persons become skill resources only when they consent to do so, whereas computational environments are available at the bidding of the user.

Keywords — situated learning in the workplace, environments for open-ended and termless learning, theories of collaboration and learning, distributed cognition, life-long learning, learning on demand, learning webs, domain-oriented design environments.

1. Introduction

In our research over the last fifteen years, we have created conceptual frameworks and innovative systems and we have conducted assessment studies to address problems of working, learning, and collaboration with computational artifacts. The content domains of our work are design activities in which design is understood very broadly as the process of determining how things ought to be (Simon 1981). Design can be seen as a fundamental activity within all professions. It is a collaborative, argumentative process without optimal solutions but with trade-offs. It is impossible for design processes to account for every aspect that might affect the designed artifact. Therefore, design must be treated as an evolutionary process, in which all stakeholders continue to learn new information and insights as the process unfolds (Fischer, McCall et al. 1994).

The necessity to intertwine learning, working, and collaboration results from the growing recognition that in the information age, change is unavoidable and obsolescence is guaranteed. Learning can no longer be considered a process that occurs only in schools. We have to think of learners not as being inherently isolated but rather as having to learn to make new, different, and strategic uses of the sources of information around them. The successful student or professional is one who learns how to use research materials, libraries, and computational environments, as well as knowledgeable humans (parents, teachers, peers, mentors, and practitioners from other disciplines) to master complex problems.

2. Distributed Cognition: Limitations of the Individual, Unaided Human Mind

2.1. Limitations of the Individual Human Mind

Human beings have a bounded rationality (Simon 1981). There is only so much we can remember and there is only so much we can learn. Talented people require approximately a decade to reach top professional proficiency. These general observations provide the rationale that, when a domain reaches a point where the knowledge for skillful professional practice cannot be acquired in a decade, specialization will increase, teamwork will become a necessity, and practitioners will make increasing use of external reference aids (such as printed and computational media). With powerful technologies becoming widely available, people take on more complex jobs. Therefore, they need help in accomplishing unfamiliar tasks that are part of an expanded job. Beyond the need for new and changing domain knowledge, there is also a large demand for new tool knowledge.

2.2. Distributed Cognition

Learning is part of living, a natural consequence of being alive and in touch with the world, and not a process separate from the rest of life. Acquiring knowledge cannot be restricted to obtaining a prescribed education at a given time. What learners need, therefore, is not only instruction but access to the world (in order to connect the knowledge in their head with the knowledge in the world). Education should be a distributed lifelong process by which one learns material as one needs it. Distributed cognition (Norman 1993) is a necessity in response to the limitations of the individual human mind.

Distributed cognition needs to include humans and things, and the two infrastructures should complement each other. Humans (e.g., coaches, peers, practitioners from other domains) have extensive background knowledge and a shared understanding unavailable in things. Things can store information (e.g., books), highlight relevant information (e.g., graphs, mathematical notations), and retrieve, compute, and analyze information (e.g., different forms of computational media).

3. Learning Webs

Illich (Illich 1971) (long before the world-wide web and the information superhighway were a reality) has envisioned learning webs as an alternative and augmentation to traditional schooling. The major objectives that he envisioned his learning webs would provide were (1) reference services to educational objects, (2) skill exchanges, (3) peer matching, and (4) reference services to educators-at-large. Many collaboration technologies (e.g., most Computer-supported collaborative work systems) employ the computer as a medium with few interpretable components. Future computational environments need to integrate humans and computational resources more creatively. Computational environments that can interpret objects, actions, and artifacts (not only from a tool perspective but also from a domain perspective) can make information and resources available at the bidding of the user, whereas persons become skill resources only when they consent to do so, and they can also restrict time, place, and methods as they choose.

To increase the computational support of collaborative environments, a limited shared context must be established. General-purpose information spaces can have only a limited notion of users' tasks at hand. Domain-oriented design environments (DODEs) (Fischer 1994) exploit domain semantics and the design context to actively notify designers when there is information they should know. Many current design systems are limited because they function only as "keepers" of the artifact, in which one deposits representations of the artifact being designed. Our experience has shown that designers integrate designing and discussing in such a way as to make separate interpretation difficult (Reeves 1993) .

4. Domain-Oriented Design Environments

DODEs have emerged in our research work as computational environments in support of collaboration. They are semiformal systems that integrate object-oriented hierarchies of domain objects, rule-based critiquing systems, case-based catalog components, simulation components, checklists, and argumentative hypermedia systems. They support communications and negotiations among all involved stakeholders and between the designers and their work in progress. They do limited reasoning and interpretations, trigger breakdowns, deliver information, and support the exploration of the rationale behind the artifact.

The goals associated with DODEs are (1) to bring task to the forefront by supporting human problem-domain interaction, (2) to create a shared context between designers and computational environments, (3) to create an artifact-centered information repository facilitating collaboration among all stakeholders, (4) to support learning on demand and information delivery, and (5) to have human designers in control. The theories underlying DODEs are (1) to make objects and ideas ready-at-hand, allowing learners to communicate more directly with the task, (2) to support reflection-in-action (Schön 1983), (3) to integrate problem framing and problem solving, (4) to allow design-in-use, and (5) to increase the back-talk of the situations (Fischer, Lemke et al. 1991). The users of DODEs are skilled domain workers who belong to the community of practice that a specific DODE supports.

4.1. An Example: The Voice Dialog Design Environment

The Voice Dialog Design Environment (VDDE) (Repenning and Sumner 1992) will be used to illustrate our conceptual framework. Voice dialog interfaces consist of a series of voice-prompted menus. Users press buttons on a telephone keypad and the system responds with appropriate voice instructions. Current interface design techniques for voice dialog systems are based on flow charts. It is difficult for designers, customers, and end-users of these systems to anticipate how the (audio) interaction will sound by simply looking at a static visual diagram. To experience breakdowns, simulations are needed that can serve as representations for mutual understanding by allowing designers, customers, and end-users to "experience" the actual audio interface.

The VDDE allows domain designers to create graphic specifications using a gallery of domain-oriented components and worksheets on which designers create a specific design. The behavior of the design can be simulated at any time. Design simulation consists of a visual trace of the execution path combined with audio feedback of all prompts and messages encountered.

Earlier versions of VDDE did not contain a critiquing component, limiting the "back-talk" to the designers and the learning opportunities provided for them. Voice dialog design is complicated by the fact that there are different rule sets that should be obeyed by a design. VDDE-Critics (Harstad 1993) adds critics to VDDE to signal additional breakdowns for the designers. In addition to earlier critiquing systems, VDDE-Critics allows designers to tailor the "breakdown" characteristics of the system to their personal needs by (1) selecting the rule set and the associated argumentation to be used, (2) determining the intrusiveness of the critiquing mechanisms with the critiquing thermometer, and (3) choosing the design component to be critiqued (a conceptual unit versus the overall design).

4.2. A Process Model Illustrating Collaborative Processes in Design Environments

Design problems are intrinsically ill-defined, open-ended, and "wicked," making it impossible to predict, let alone collect, all the potentially relevant information in advance. They must capture information continuously over the lifetime of the system and make that information available to designers when it is relevant to their particular tasks. We have developed the SER model, a process model for the evolution of domain-oriented design environments (Fischer, McCall et al. 1994) consisting of three phases: seeding, evolutionary growth, and reseeding.

During seeding, environment developers and domain designers collaborate to create a design environment seed. During evolutionary growth, domain designers create artifacts that add new domain knowledge to the seed (i.e., new knowledge is generated and integrated into the environment by the domain designers themselves rather than produced by the environment developers). In the reseeding phase, environment developers again collaborate with domain designers to organize, formalize, and generalize new knowledge.

4.3. Increasing the Situation Awareness

Design is a well-suited activity to explore concepts in collaboration because the design activity takes place *within* the computational environment. The "situation awareness" of a DODE is increased through the following mechanisms: (1) the domain orientation allows a default intent to be assumed, namely, the creation of an artifact in the given domain; (2) the construction situation is accessible and can be "parsed" by the system, providing the system with information about the artifact under construction; (3) the specification component allows one to explicitly communicate high-level design intentions to the system; and (4) the embedding of annotations contextualizes messages to other stakeholders rather than communicating them in a decontextualized e-mail message.

4.4. Learning on Demand and End-User Modifiability

DODEs provide learning-on-demand opportunities (Fischer, Lemke et al. 1991) for a designer through critiquing, simulation, and access to contextualized argumentation and cases. But the information flow is not only one-directional. Using DODEs, designers will transcend the existing knowledge and contribute new knowledge themselves. Because these designers are domain designers and not software designers, end-user modifiability support is required.

End-users may wish to have functionality that fits their needs, but the creation of this functionality is a difficult task. Two major approaches, namely programmable design environments (Eisenberg and Fischer 1994) and collaborative work practices (Nardi 1993), make end-user programming a more realistic challenge. Collaborative work practices, leading to the development of power users and local developers, are naturally developing practices in communities where end-user modifiable tools are available.

5. The Support of DODEs for Collaborative Learning—Lessons Learned From Our System-Building Efforts

If things are basic resources for learning, then the quality of the environment and the relationship of persons to them will determine how much they will be able to learn. DODEs are instrumental versions of systems that are *simultaneously* user-directed and computationally supportive (thereby complementing open learning environments and intelligent tutoring systems with an additional alternative). DODEs support human problem-domain communication by reducing the demands of learning about the tool. They offer a variety of different learning opportunities through critiquing, simulation, argumentation, and examples. Having an increased situational awareness through the integration of the different components, DODEs are able to incrementally obtain a partial understanding of the task at hand and to contextualize information to it.

While cognitive questions and content are important, collaboration technologies raise numerous other issues. What will make people want to share? What will motivate people to make their knowledge explicit and contribute it to an organizational memory (especially, if they have to do the work but are not necessarily the beneficiaries of it)? These questions will in the long run be more important than technological issues, and successful models to answer them positively are still quite rare.

One of the benefits of integrating working and learning is the potential increase in motivation. Motivation to learn new things is critically influenced by optimal flow, a continual feeling of challenge, direct engagement, the right tools for the job, and a focus on the task (Csikszentmihalyi 1990). Users are willing and motivated to learn when the following conditions hold:

(1) They actively desire and control learning—supported in DODEs by the integration of working and learning allowing learners to be engaged in authentic, self-directed activities.

(2) They are successful in finding and using new information—supported in DODEs by contextualizing new information to the task at hand and to breakdown situations.

(3) They can see the immediate benefit of learning something new to their current working situation—supported in DODEs by making argumentation serve design, by locating relevant catalog examples, and by illustrating complex behavior with simulations.

(4) Their environments are intrinsically motivating and allow them to achieve interesting results with a reasonably small effort—supported in DODEs through human problem domain communication, which allows users to focus on their tasks.

6. Conclusions

Design activities require learning and collaboration. We have developed conceptual frameworks and innovative systems that support not only the creation of the artifact but also the professional communities engaged in design as professional practitioners. We have learned from our efforts that older frameworks of education—associated with notions of instructionism, memorization, and decontextualized learning—cannot be shaken merely by the presence of technology, whether that technology takes the form of intelligent tutoring systems, multimedia, or world-wide connectivity. New frameworks must instead be devised to support lifelong learning—learning webs that allow integration of learning, working, and collaborating; engagement in authentic problems; self-direction in learning tasks; and creation of new content and domain areas.

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Towards an Analytical Framework for CSCdistanceL

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Abstract

This paper presents a framework for evaluation of computer applications in relation to the new and unique phenomenon of learning: Computer supported collaborative distance learning (CSCdistanceL). The framework may also be considered a means for designing computer applications mediating human actions of collaborative learning. Problem oriented project pedagogy is used as a pedagogical foundation to understand collaborative learning. The crucial aspects of this pedagogical viewpoint are interpreted into dialectical contradictions. The contradictions constitute a basis for understanding the incorporated role of the computer application in the various human actions of collaborative learning.

Keywords — Problem oriented project pedagogy, distance learning, dialectical analysis, evaluation and design of computer-based applications.

1. Introduction

This paper is a short version of a paper with the title *An analytical framework for evaluation and design of computer applications mediating collaborative distance learning*. In this short version, only the basic argumentation and suggestions are described. The empirical basis for the framework is only briefly presented.

The framework has been developed on basis of various studies (over a period of four years and still continuing) of mainly two different learning situations in which com-puter-based applications—based on asynchronous and text-based communication—have a crucial but different role: One learning situation has its foundation in the long tradition of distance education—correspondence education. The pedagogical model is based on an information-transmission paradigm of learning and communication, in such a way that individual production of texts and distribution of these for comments are emphasised. The computer-based application is considered a medium for socialisation in learning situations characterised as highly individual and independent.

The other learning situation has its foundation in a pedagogical viewpoint introduced (in Denmark) by the Danish pedagogue Knud Illeris, who developed what he called an alternative didactic (Illeris, 1974). This pedagogical viewpoint is problem oriented project pedagogy. The fundamental principle is that the students constitute an indivisible community in the collaborative process of analysing a phenomenon in relation to present conditions and problems of society. In contrast to a learning situation analogous to an information-transmission paradigm of communication, the intention has been to integrate a computer application *not* only to distribute written texts, but to articulate individual contributions and to mediate interaction between the peer-students, to get the whole cooperative work done.

In spite of the two different pedagogical viewpoints, the both learning situations are considered a complex and conflicting frame of computer supported distance learning because of various factors, and the interdependence between them: Pedagogical aspects, technical factors directed towards the limitations and possibilities of avail-able computer applications, administrative and organising factors, factors directed towards design of courses and subject matters, human attitudes, etc. These interconnected factors are crucial to understand CSCdistanceL as a new and unique phenomenon of learning, and indicate that the computer application does not necessarily have the crucial meaning of a successful learning process. However, the signification of available computer applications has most critical *pedagogic consequences* in learning situations emphasising the students interdependency in their work. In such situations, the communication structure presented in the available text-based and asynchronous computer applications constitutes a conflicting frame in relation to the dynamic process of inter-human actions.

This paper is restricted to focus on the interconnection between 1. *Human actions directed towards the colla-borative learning process*, and 2. *The computer application.* This relationship is the point of departure for a framework developed for evaluation of computer application in relation to CSCdistanceL. A fundamental assumption is that a framework developed on basis of problem oriented project pedagogy, will cover the most crucial aspects of collaborative learning in such a way that the framework can be applied in relation to *other and less complex viewpoints* on collaborative learning at distance.

Section 2 presents the problematic domain of this relationship. Section 3 presents the analytical framework based on this problematic domain, and section 4 briefly discuss how it can be applied.

2. The Contradiction between Computer-based Applications and Collaborative Learning

A fundamental requirement of collaborative learning is that a common environment of shared recognition and ex-perience is established (c. f. e. g. Schrage, 1990). Such a community is not created by simply a process of information transmission and distribution (Schrage, 1990, Lave and Wenger, 1991) or assimilation (Piaget, 1950, Illeris, 1974), but in a process in which the students have a certain degree of obligation to each other. The students may have different interests, hold various viewpoints and meanings, and make diverse contributions to the actions. However, the participating students need to have a shared understanding concerning what they are doing and what that means for their individual development process and for the development of the learning community which they are a part of (c.f. Lave and Wenger, 1991).

The primary target group for most distance- and open learning situations, is the adult work force of our society. The student—the adult worker, usually with an established life with family and friends—needs a flexible (further) educational situation free from place-, and often time, constraints. In collaborative learning at *distance*, a computer application designed for collaborative activities is a fundamental means to create a community of shared experience and recognition. However, such a community is only created if the computer-based application mediates the human actions in such a way that the individual students *do have a feeling of participating* in such a community. A basic assumption for this is that the computer-based artefact is incorporated in various human actions varying in relation to the situation at hand. With basis on this assumption, CSCdistanceL must be understood as two incorporated aspects: 1. *Human actions directed towards the collaborative learning process*, and 2. *The computer application.*

Computer applications applied in most distance- and open learning situations (cf. Fjuk, 1993, Mason and Kaye, 1989, Kaye, 1992, Mason, 1994, Georgsen and Dirckinck-Holmfeld, 1993), represent a written and asynchronous communication form (various computer conferencing systems, bulletin board systems and e-mail systems). This category of computer applications is widely used because of their technical and economical *availability* for the target group. Because of the requirement of flexible learning situations, the students need to participate in the learning process from places most convenient for them, from their homes. Consequently she has not powerful, expensive computers and software, and broad-band networks available. These technical means are often considered as a requirement for collaborative activities (c. f. e. g. Bannon and Schmidt, 1992), and are e. g. available for students participating in CSC(distance)L from the campus of a university and a college.

The text-based and asynchronous communication form presented in most of the available computer applications, represents an information-transmission paradigm of inter-human interactions. Dialogues take place with an analogy to the process of writing, sending and receiving a letter (Sorensen, 1991). Thus, the dynamic and spontaneous nature characterising a dialogue is fundamentally on the premises of the written language. The dialogue lacks the expressive power and interpretative cues resulting from the loss of visual information and feedback opportunities (Eklundh, 1986). In distance learning situations, the written and asynchronous dialogue is the dominating aspect of cooperation, because the students to a large degree do not have any other possibilities to cooperate.

The students report that in a collaborative learning process—based on problem oriented project pedagogy (see next chapter)—it is extremely time consuming and a factor of frustration to carry out inter-human actions directed towards consensus seeking and inter-human conflicts in general, but especially in the fundamental problem formulation phase and in the articulations of each other's contributions to the project (Løth and Køhler, 1995, c. f. e. g. Georgsen, 1995, Dirckinck-Holmfeld and Fjuk, 1995). The students emphasise that the computer application is a means to support competition and authority, rather as a means to support creativity, mutual respect, tolerance and trust. This may imply a feeling of independence and freedom (Eklundh, 1986), and the students may have a reduced perception of being an active participant in a common learning community (Georgsen, 1995). The feeling of mutual commitment and mutual interdependence, which is essential to create the common learning environment, may not appear in the individual student's mind.

Thus CSCdistanceL as a phenomenon of learning, implies a conflicting relationship between the two incor-porated aspects: *Human actions directed towards* *the collaborative learning process*, and *the computer application*. These two aspects are presupposing each other. At the same time the aspects are conflicting each other and may cause a dissolution of the relationship between them. This conflicting frame may have crucial pedagogical consequences. However, the degree of the consequence is dependent on the fundamental perspective on collaborative learning. In learning situations not having the main focus on inter-human interactions and mutual commitment, but having the main focus on production of texts and information distribution, this conflicting frame is not so obvious. In such situations, the communication structure presented in the computer application and the basic view of learning, represent both an analogy to an information-transmission paradigm of communication. However, the conflicting frame may be present because of other aspects (out of the scope of this paper).

The relationship between the two aspects is fundamental to understand CSCdistanceL as a phenomenon; It distinguishes and characterises the learning form from other learning forms.

Such an understanding of CSCdistanceL is analogous to Mao Tsetung's (1972) concept of *fundamental dialectical contradictions*: The contradiction that characterises a phenomenon and distinguishes it from other phenomena. A contradiction consists of two aspects, simultaneously and mutually presupposing and conflicting each other. In general, dialectical theory is suitable to describe and understood the wholeness of situations and phenomena that are characterised as complex and difficult to penetrate into (Øgrim, 1993). Every phenomenon is understood in an interplay with its surrounding environment, and every phenomenon is understood as a number of contradictions that are interconnected. Mao's interpretation of dialectical contradictions is to a larger degree than Hegel's these-antitheses-and-syntheses schema, concentrated on the dynamics within a contradiction (ibid.), i. e. one of the aspects of the contradiction will—dependent on the situation—dominate the phenomenon. However, the objective in some situations is to create a balance between the two aspects (ibid.). CSCdistanceL is understood as a new and complex phenomenon of learning, and the dominating aspect of this phenomenon of learning has been the computer application. The artefact forces the participating students into rigid and artificial structures of human actions similar to a information-transmission paradigm of communication. An analytical framework considering collaborative learning as complex whole phenomenon of human actions—and not simply as information transmission and presentation—is thus needed.

By using Mao's concepts of dialectical contradictions, CSCdistanceL is understood as the fundamental contra-diction consisting of the two presented aspects. This contradiction is considered as the point of departure for developing a framework emphasising the dynamic balance between the two aspects.

3. The Analytical Framework

Problem oriented project pedagogy is applied as a basis for the framework, firstly because it emphasises crucial aspects for creating a common learning environment: Inter-human interactions and -relations, and a certain degree of commitment between the participating students to gain both individual and collective development of knowledge and experiences. Secondly, it is an *analytical viewpoint* without any principles and strongly directing methods for learning. The fundamental principle is to contribute to changes and development in society through critical atti-tudes and awareness in relation to the conditions of socie-ty. Learning is organised as *cooperative work in projects* and this organising of learning can then be considered a certain kind of work. The analytical viewpoint has, because of these facts, a close relationship to the social practice of work and cooperative work. Totally, project oriented project pedagogy can be analysed in combination with theories from work and cooperative work. When it comes to the computer application's role in this—to understand CSCdistanceL as a learning phenomenon—theories and empirical research from the close related field of CSCW can be applied.

Figure 1 illustrates the analytical framework. The fundamental contradiction is shown to the left of the figure. The fundamental contradiction is further analysed by considering two sub-ordinated contradictions: 1. The contradiction between *work task and cooperation*, and 2. The contradiction between *tool and medium*. These contradictions—and the relationship between them—are presented in the next two sub-sections.

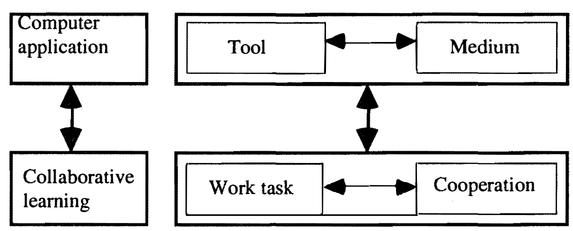

Figure 1. The analytical framework of CSCdistanceL.

3.1. The relationship between work task and cooperation

Problem orientation is a work-method, which prerequisite that there exist a problem that can be recognised and experienced as a conflict, a need, and a wish of changes. A problem does not have a prerequisite solu tion for the students, but is considered as something to understand and to penetrate into. The work tasks have to be directed towards conditions and problems of society. According to Illeris (1974), problem orientation can not alone be considered as fundamental. An other critical aspect is participants' control (Danish: deltagerstyring), i. e. the students have the responsibility for their own actions through active participation. The students represent an indivisible community that manage the participants' control, in such a way that they have a shared understanding concerning what they are doing and what that means for the individual learning process and for the development of the collaborative community. The relationship between participants' control and problem orientation is dialectical.

The fundamental principle of problem oriented project pedagogy can be interpreted as a dialectical contradiction between *the superior problem presented in various work tasks* and *cooperation*. Cooperation is the common term of *inter-human interactions*—and mutual commitment—and *articulation of the students' contributions*. Such an understanding of collaborative learning can be interpreted analogous to what Schmidt (1994) has termed cooperative work: Interdependency in work. Although cooperative work is a collective phenomenon of work, each action is often conducted by an individual actor directed towards a work task. This means that most work tasks are carried out by an individual, but the peer-actors are mutually interdependent in their work (ibid.) in the sense that they need to coordinate and articulate their actions to get the whole work done. In collaborative arrangements, there is a web of actions; informal and formal information exchange, individual (and sometimes collective) work tasks are discussed, handled, solved, etc. All of these actions are more or less interwoven and incorporated, dependent of the current situation.

3.2. The relationship between tool and medium

The dialectical contradiction between (problem-oriented) work tasks and cooperation, are considered fundamental to understand how a computer application should mediate the web of human actions in a collaborative learning community. The dynamic interplay between the web of human actions, implies that a computer application has different roles in different situations. In some situations the application has the mediating role between an individual and her peer-students. In other situations the application has the mediating role between the individual and her work tasks. Thus, the application has to be understood analogous—and as a support to—the contradiction between cooperation and work tasks. The computer application can not simply be understood as a medium for communication (cf. Maaß and Oberquelle, 1990)—information transmission—but as a medium for inter-human interactions and articulation of individual work. The application should also be understood as a tool to allow the student to concentrate on the goal of her work tasks (c. f. e. g. Ehn, 1988), Maaß and Oberquelle, 1990).

The computer application should then be understood in terms of a dialectical contradiction, to support the whole phenomenon of CSCdistanceL. The relationship between the two rectangles in figure 1 (illustrated with the vertical arrow) illustrates how an application is incorporated in a web of human actions in collaborative learning. Thus, the analytical framework for evaluation—and further for design—of computer applications is understood as a dynamic interplay between aspects of the computer appli-cation (tool and medium) and aspects of collaborative learning (problem oriented work tasks and cooperation).

4. Final Remarks

The expanding usage of e-mail, WorldWideWeb, computer conferencing systems, group-ware, etc., has reached the educational part of our society. But changes in how learning is organised put new or other requirements to the applications as a consequence of their usage in 'real situations' outside the laboratories.

The analytical framework presented in this paper can be applied to evaluate what applications that are most useful in what learning situations. The framework can also be used as a means for designing new applications for collaborative learning.

The dialectical contradiction between work task and cooperation, indicates that if a computer application should mediate collaborative learning, it should mediate human actions directed towards *both* individual work tasks and cooperation. If the application mediates actions related to only one of these aspects, it does not mediate the whole collaborative learning process. For example, if a computer application only mediates actions directed towards cooperation—and only *some* aspect of it—it does not mediate the whole process of collaboration.

The asynchronous and text-based communication applications available for the target group of most distance learning institutions—'the home-students'—represents *some* premises for cooperation: Distribution, transmission and presentation of information in written form. A learning situation in which individual and independent production of written contributions and distribution of these are emphasised, the applications do not cause a crucial con-flicting frame. Interdependency in work is not emphasised. This factor is however crucial in learning situations in which a *shared environment* for recognition and experience is fundamental. In such situations, the available applications do only mediate a limited part of the whole process of creating and manipulating a collaborative community.

Computer applications supporting the dynamic inter-play between various human actions of collaboration are on their way out of the laboratories. However, these applications are not technical and economical available for the adult working people of society—having the need to take part in a collaborative learning community from the places most convenient for them—from their homes. The further challenge is to develop applications supporting *their needs*.

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Collaboration through Concept Maps

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Abstract

Concept maps have been used in education, policy studies and the philosophy of science to provide a visual representation of knowledge structures and argument forms. They provide a complementary alternative to natural language as a means of communicating knowledge. In many disciplines various forms of concept map are already used as formal knowledge representation systems, for example: semantic networks in artificial intelligence, bond graphs in mechanical and electrical engineering, Petri nets in communications, and category graphs in mathematics. This paper describes the design and applications of groupware concept mapping tools designed to support collaboration in dispersed learning communities.

Keywords — Concept maps, World-Wide Web, collaborative learning.

1. Introduction

It is no coincidence that the words image and imagination have the same roots. It has been known from early times that visual imagery plays a significant role in the creative processes of many people [1]. The availability of low-cost, high-performance graphic workstations and personal computers has made it possible to support visual thinking processes in a variety of ways across a wide range of disciplines, and again has led to a major literature on *visualization* [2]. There is also a large and growing literature on the use of computer-based tools to support *visual languages* for a wide variety of structures [3].

The activities reported in this article are part of a long-term program of research on the technology and applications of computer-based collaborative systems to support individuals and groups in creative visualization. This report focuses on our studies of concept mapping techniques, their implementation on personal computers, their use in collaborative learning over digital networks, and their integration with World-Wide Web (WWW) servers and browsers.

2. Concept Maps

Many disciplines developed visual languages for 'concept maps', 'cognitive maps' and 'argument forms.' In education, Novak and Gowin [4] developed a system of concept maps that has been widely applied in the evaluation of students' learning in the school system [5]—Figure 1 shows a map from these studies.

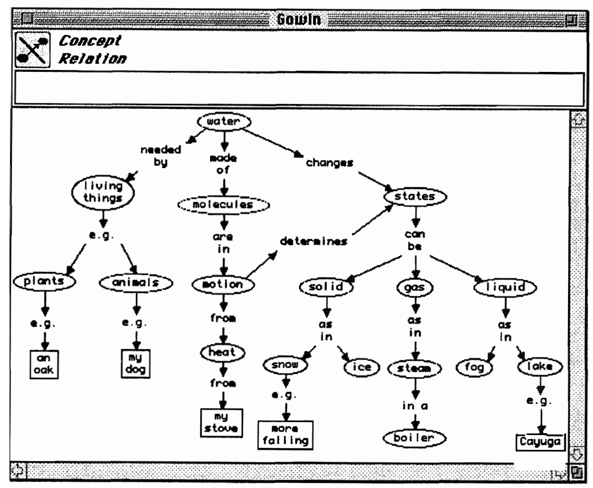

Figure 1. Concept map of student's knowledge.

A wide variety of different forms of concept map have been applied in education [6]. In management, Axelrod proposed cognitive maps as a means of representing the conceptual structures underlying decision making [7]. In the history of science, the dynamics of concept maps have been used to represent the processes of conceptual change in scientific revolutions [8, 9]. In the philosophy of science, Toulmin [10] developed a theory of scientific argument based on typed concept maps.

3. KMap: A Concept-Mapping Tool

We have developed a general concept mapping tool called KMap [11, 12] which provides a grapher for nodes and arcs that can be programmed by the user to support different forms of concept map. User interaction with KMap takes place through the creation of statements in the visual language, and through interaction with such statements through popup menus whose content is specific to node type. The action initiated is context-sensitive: to the node selected for the popup, to nodes linked to it, and to other nodes preselected by clicking on them. This allows complex activities to be initiated by natural user actions.

Figure 1 was drawn in KMap, and Figure 2 shows one of local applications [11] in graduate education where students are introduced to the structure of a research program through an interactive concept map that may be edited and linked to their own research. The node types and content may be edited by the students, as may a database of information attached to the nodes that provides links to other concept maps and files, either locally or across the Internet. For example, the student has moused over a node on objectives concerned with the determination of the current state of the art, and moused down when the cursor changed to a popup menu icon to access a menu giving access to a local file of her supervisor's notes and a WWW file of her own notes put up as part of a course.

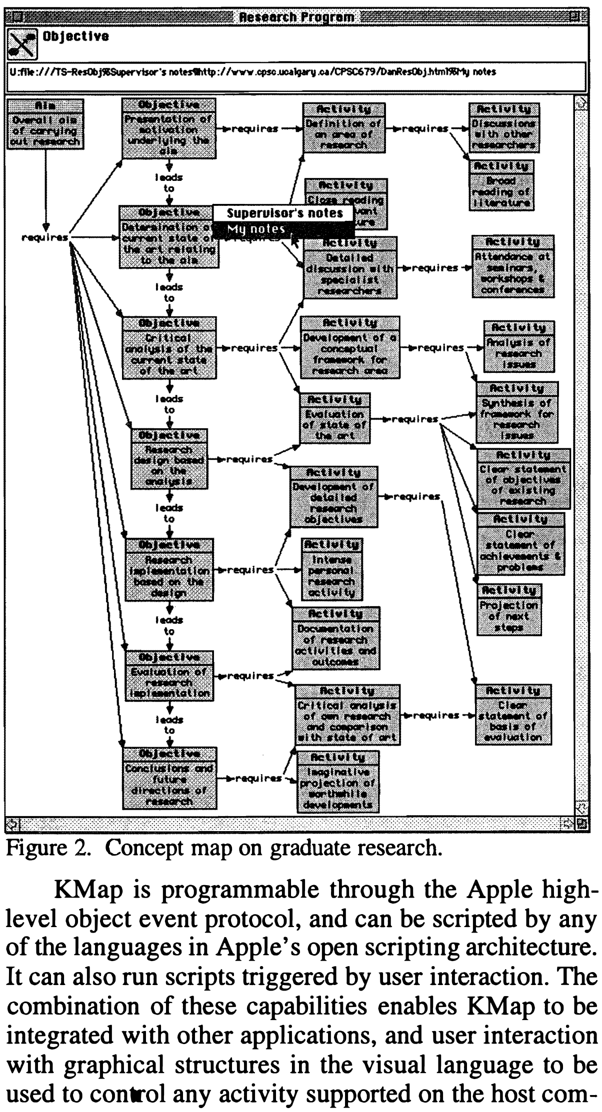

Figure 2. Concept map on graduate research.

KMap is programmable through the Apple high-level object event protocol, and can be scripted by any of the languages in Apple's open scripting architecture. It can also run scripts triggered by user interaction. The combination of these capabilities enables KMap to be integrated with other applications, and user interaction with graphical structures in the visual language to be used to control any activity supported on the host computer or network.

Figure 3 shows a user interacting with a map of multimedia materials concerned with the identification of birds. The map gives an overview of the topic and acts as an index to available material. As the user mouses over a node a popup menu symbol appears. Clicking on this displays a menu that can be used to access the material, display text, play a sound, run a movie, and so on. The menu is generated from an underlying script, and user actions are reported to the script. The material accessed can be retrieved using either standard facilities for sound and movie playing within the application, or through commands which initiate another application and appropriate dataset. The actions can include the opening of other concept maps so that is possible to index a large body of material through layers of connected maps.

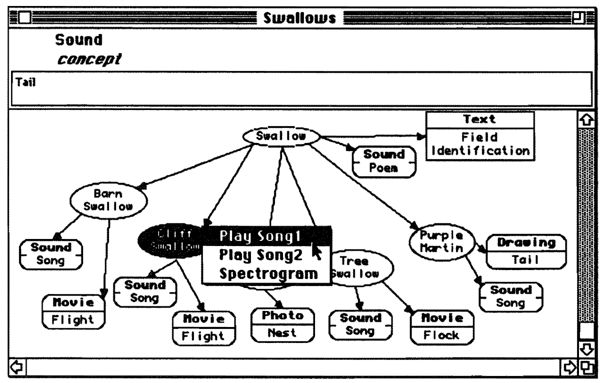

Figure 3. Concept map of multimedia materials.

Figure 4 shows the generation of the visual language used in Figure 3. The designer generates nodes of different types appropriate to the domain of materials to be accessed. The visual features of each type can be designed to be distinctive and attractive. The script can associate simple retrieval activities for each type dependent on the data stored with each node, or, since it has full access to the concept map, can take context-sensitive actions as appropriate.

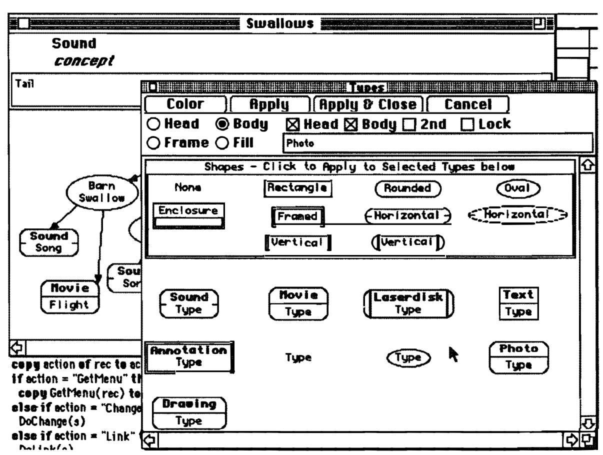

Figure 4. Entering concept map types to define a visual language.

4. Collaborative Access to Concept Maps

One of the major objectives of our research in the last two years has been to port all our interactive systems, currently on personal computers and local area networks, to operate effectively in the open, wide area networking of the Internet, and, wherever possible, to integrate seamlessly with World-Wide Web. However, the graphic primitives necessary for interactive concept maps are not provided in HTML and it is a challenge to port concept maps to WWW.

It proved simple to operate KMap as a WWW *client helper,* capable of accepting concept maps brought across the WWW by a browser such as Netscape, and of requesting arbitrary files, including concept maps, to be fetched through messages sent from KMap scripts to the WWW browser. Figure 5 shows an HTML document in Netscape which has links to KMap documents.

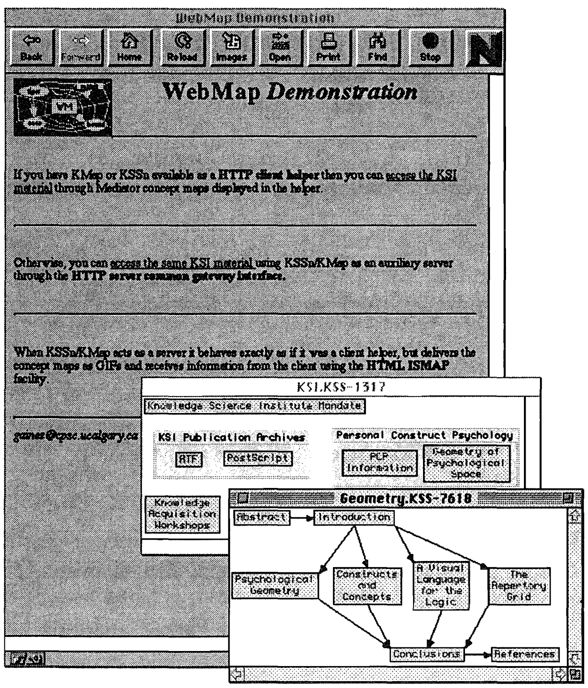

Figure 5. KMap acts a client helper application to the NetScape browser.

When the user clicks on the hypertext link "access the KSI material" at the top of the screen, Netscape fetches a KMap file "KSI.KSS" which it passes to KMap which open and displays it as shown in the KMap window at the middle right.

Clicking on the node "Geometry of Psychological Space" at the right of this map causes KMap to send a message to Netscape requesting that the file with url "http://ksi.cpsc.ucalgary.ca/WebMap/Geometry.KSS" be fetched. This is a concept map of the structure of an article that opens in another KMap window shown at bottom right. Clicking on the node "Constructs and Concepts" in the center of this map causes KMap to send a message to Netscape requesting that the url "http://ksi.cpsc.ucalgary.ca/PCP/PCPInto.html#4" be fetched. This is a section of an HTML document that NetScape then displays. Clicking on other nodes in the concept map causes NetScape to navigate to different sections of this document.

KMap is currently implemented only for the Apple Macintosh and hence can act as a client helper only on Macintosh computers. We are currently working on ports to Windows and Motif which will make KMap helpers available on all major platforms. However, there will always be users who do not have, or want to use, the helpers but where it is appropriate to provide non-editable concept maps as *clickable maps* in HTML documents. We have interfaced KMap as an auxiliary server through the *common gateway interface* to MacHTTP to allow the same concept maps to be used as clickable maps.

Figure 6 shows the file fetched when the user clicks on the "access the same KSI material" in the second paragraph of the document of Figure 5. KMap converts the concept map to a GIF file and delivers it as an image that Netscape can read.

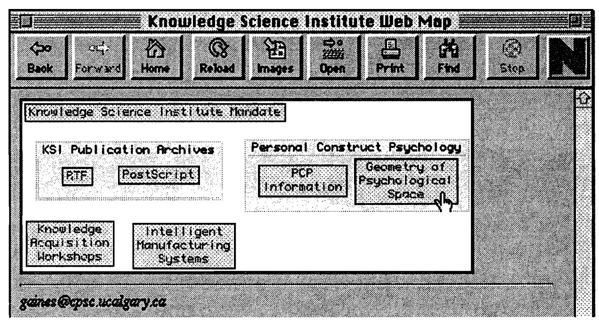

Figure 6. KMap acting as a server through the common gateway interface to MacHTTP.

Clicking on the node "Geometry of Psychological Space" sends the coordinates of the point clicked back to KMap on the server which then takes the same action as if the map had been clicked in a helper. Thus KMap supports the use of concept maps on World-Wide Web through client helpers and server gateways in an integrated way.

5. Applications to Collaborative Learning

We have previously reported experience in the use of concept maps to support creative processes in collaborative learning situations [11]. Our approach has been to have individual students develop concept maps for their domain of interest and link them to associated materials. Other students then critique these maps, modifying them, or adding to them, to provide alternative versions.

Sometimes consensual maps are developed by negotiation. At other times the absence of such consensus is the major learning experience since it demonstrates the plurality of incompatible perspectives available.

Students working in collaborative groups usually divide responsibility for the domain, and produce networks of linked maps and associated materials. These can grow to become very complex, particularly if they are part of long-term activitie such as those of a research group.

One of the problems in the past has been to support concept mapping across distributed groups, and to make the materials developed more widely available. The move to World-Wide Web overcomes the limitations of tools operating only on local personal computers, and the capability to use concept maps as WWW "clickable maps" makes it possible to provide access to material to anyone using any platform with a WWW browser.

6. Conclusions

Concept maps have a long history of being used in support of learners and, in general form, to support a wide variety of visual thought processes in individuals and groups. This article has shown how computer-based concept mapping tools may be used to support collaborative learning by sharing maps on personal computers, working together on linked maps on different workstations, and sharing maps across World-Wide Web. In particular, it has shown that a single tool can be designed to have the flexibility to operate in all these modes. The class library architecture used to implement KMap is described in detail elsewhere [13].

The graphic capabilities necessary to support interactive concept mapping are currently missing in WWW protocols and browsers. We see them as a major omission, and are committed to providing concept map support on WWW, through client helpers for the major platforms that will ultimately support maps embedded in documents through OLE II and OpenDoc protocols.

We believe that concept mapping techniques accessible through the World-Wide Web will provide significant support for many forms of collaborative learning.

Acknowledgments

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Theory Sequences in a Problem-Based Learning Group: A Case Study

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Abstract

Problem-Based Learning (PBL) fosters the development of reasoning strategies via interactive, social processes. The act of theorizing is a component of reasoning being developed in PBL settings. This conversation analytic study investigates the social construction of theorizing in a discussion which takes place in a PBL setting with medical students. Specifically, we describe one instance of theorizing, including theory presentation, treatment, and subsequent ratification by the group. This study holds implications for understandings reasoning as an interactive process.

Keywords — social construction of theorizing, conversation analysis.

1. Introduction

Problem-based learning (PBL) is a collaborative, case-based, and student-centered method of instruction (Koschmann, Myers, Feltovich, & Barrows, 1994; Williams, 1992). In a problem-based curriculum, authentic problems drawn from clinical practice serve as the stimulus for learning (Barrows, 1994). The method begins with presentation of a problem to a group of students (usually six to eight is considered optimal) and a faculty facilitator known as the "coach" (Koschmann et al., 1994). In a setting unaugmented with technology, the group records their deliberations on a whiteboard provided for the purpose. The students, relying on their pertinent prior knowledge, attempt to analyze the problem and to identify areas for further individual study. When the group recesses, the students proceed to identify and utilize resources—person, print and electronic—which provide the additional knowledge necessary for understanding and managing the patient problem.

Our ongoing conversation analytic (see Atkinson & Heritage, 1984) research project involves focusing upon how theories are developed, supported and appraised in PBL groups. The basis for this study was a series of videotapes done following one group of second-year medical students through their deliberations with respect to a single case (i.e., an elderly male patient complaining of problems with his memory, difficulities in "expressing himself", and transient clumsiness of his right leg).

The PBL group participants organize their meetings at least in part around the presentation of a theory plus talk orienting to that theory. Once presented, a theory sets the agenda for subsequent talk in which group members may evaluate, modify, accept, or reject the theory. They accompish these actions by asking questions, fitting evidence and reasoning to theory, producing alternative theories or accounts for data, and assessing ideas. The presentation of and responses to one theory is described below.

2. Presentation of Theory, Evidence and Reasoning: "My Theory"

The second meeting of this pbl group began with reports from the members about what each had found since their last meeting. The coach asked one of the members to summarize the case. Following this summary, the group discussed types of aphasia. At the moment where our analysis begins, the Coach provides a formulation from preceding talk of some symptoms and a conclusion (See Appendix for explanation of transcription symbols):

Coach: So he's got speech involvement 'n right leg involvement.
Maria: (   )

[

Coach: So- So whatever his problem issh (.) we're pretty confident it's on the left side

One of the students, Betty, now introduces information from a book lying in front of her:

Betty: See, what it said in here, in-

The imperative "See" brings the attention of the other group members to Betty. "What it said in here" further places that focus on the book to which she refers.

Having thus displayed that she is about to present some information, Betty now abandons that course to announce a "theory":

Betty: See, what it said in here, in- **my theory** (1.2) about this amnesic (.) dysnomic aphasia?

The possessive pronoun marks the theory as hers individually; it may also make relevant the possibility of the others presenting their own theories. As such it frames theory presentation as an individual action rather than a group action.

Betty has now prefaced two actions, each of which could warrant an extended turn at talk: presenting information from a book and offering a theory. The prepositional phrase "about this (1.2) amnesiac dysnomic aphasia," neatly unifies the two actions, for it provides a grammatically-logical referent for both what is in the book and for the theory:

((edited, simplified reconstruction))

Betty: What it says in here . . . about this amnesic dysnomic aphasia

Betty: My theory . . . about this amnesic dysnomic aphasia

Although syntactically the prepositional phrase stands closest to the "theory" she also links it to "What it says in here" by looking down at the book in front of her, apparently reading the phrase "amnesic dysnomic aphasia." The linkage of the two prefaces perhaps cues the listeners to treat the two actions as connected, such that the information she is providing stands in support of an about-to-be-presented theory. Betty quotes some from the text, then breaks off quoting to indicate that Maria (one of the other students) too had suggested what this book apparently now confirms (see **boldface** text below).

Betty: my theory (1.2) about this

[[

Coach: °mph •hh°

Betty: amnesic (.) dysnomic aphasia? (1.0) um it says the cause of lesion is usually deep in temporal lobe

just like Maria was saying Presumably interrupting connections of sensory speech areas with the hippocampal and parahippocampal regions (1.0) and I think the hippocampus is like a lot more medial.

So if it was affected in that area it might be the anterior cerebral circulation.

The allusion to what Maria was saying acknowledges that Maria was correct; it also adds Maria's voice to the book's in support of Betty.

Betty quotes more from the book, about consequences of a lesion in the temporal lobe. She stops reading and there is a one second pause. Others remain silent; this may reflect their orientation to the dual-action structure (reading and presenting a theory), and the fact that she has not yet actually offered a "theory." Betty looks up, displaying that she has stopped reading, and via "I think" she marks what is to follow as tentative. This next statement concerns the location in the brain of the hippocampus, posited as a spatial comparison ("a lot more medial"). She presents her reasoning leading to the conclusion (that is, the "theory") that anterior cerebral circulation is the source of the problem for this patient.

3. Response to Theory: Implicit Endorsement

Betty has now presented evidence and reasoning leading to a concluding theory. How do the others treat this theory? As Betty nears completion of her turn, Norman says the word "anterior" in unison with her. This bit of overlapping speech occurs at what elsewhere has been described as a recognition point, an earliest possible moment at which a co-participant may show understanding and ability to anticipate the substance of utterance completion (see Jefferson, 1973, 58-59).

Betty: So if it was affected in that area it might be the **anterior** cerebral

[
Norman: **Anterior.**
Betty: circulation.

Norman thereby can show that, given Betty's reasoning, he too arrives--independently--at the same conclusion. Perhaps this collaborative completion may also serve as a way to demonstrate alignment, if not outright agreement, with her theory.

At this point the Coach leads the group into a discussion (not shown in this paper) devoted to having the students identify the hippocampus on a flip chart showing various views of the brain. Following this, Betty presents a second theory (not shown). In contrast to the first one, this second one gets no support from any other group members; in fact, it draws critical questions and possibly disaffiliative laughter (not shown). Maria and Norman list symptoms which "you would expect" if the second theory were true. Betty then concludes in favor of the first theory, which invoked ciruclation problems to account for the symptoms:

Maria: Headaches, you would expect=
Norman: =You would expect headaches=
Betty: =°Yeah, maybe°=
Maria: =Seizures.
(?) °Mm hm°
Betty: **Um- (0.7) It's more likely to be vascular.**

Coach legitimizes this conclusion as valid by his subsequent actions. His "okay" moves them on to next matters (see Beach, 1993), and he asks a question which presumes "vascular" to be at least plausible enough to provide a basis for further theory construction:

Betty: Um- (0.7) It's more likely to be vascular.
(2.4)
Coach: **°Okay°**
[
Maria: °With his history and social°
Coach: **So so**
So if it's vascular did he have a +stroke or is he having a TIA. What is the difference between those two things anyway?

The participants have entertained two theories, rejected the second, and, if not outright endorsing the first, at least accepted it enough to use it as a basis for further questioning and theory construction. As our analysis concludes, the group seems to be pursuing the notion that this patient's problem involves a vascular lesion.

4. Discussion

In this paper we have described some organizing features of talk in one portion of a pbl group meeting. Specifically, we suggest that participants orient to the presentation of theories as a central activity. One student presents a theory and supports it with evidence and reasoning; another student displays concurrence with her reasoning. The coach then initiates discussion devoted to clarifying information relevant to the theory (not shown here). Upon completion of this clarifying task, the same student who presented the first theory presents a second theory posed as alternative to the first (not shown). This second theory gets no support from other participants, who respond with possibly -disaffiliative laughter and with critical questions (not shown). The presenter herself concludes that the first is valid. The coach uses this theory, implicitly "accepted" for the moment, as a basis for a subsequent question which leads to presentation of additional information.

Several observations seem relevant here. First, while presenting a theory may be an individual task, the "processing" of any theory (including such actions as agreeing, disagreeing, questioning, modifying, etc.) is thoroughly interactional. Second, the presentation and treatment of theories seems to be one major organizing principle in this interaction, but it is not the only one. Third, in this excerpt, both theory presentations and turns at talk are differentially distributed and such distributions provide ways to create, maintain, and modify social interactional roles such as leader, follower, critic, etc., within a group setting. Fourth, the coach intervenes at particular moments and guides the group work in particular ways. This type of activity could serve as data for future analyses. Finally, in consideration of the preceding point, this interaction involves at least two organizing frameworks or sequential contexts. One is group problem-solving or decision-making. The other is instructional, teacher-student interaction. How they make one or the other framework relevant at particular moments provides an interesting question for further exploration.

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Environments for Collaborating Mathematically: The Middle-School Mathematics through Applications Project

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Abstract

Math reforms call for deeper understandings of concepts, more collaboration among students, and use of technologies. The Middle School Mathematics through Applications Projects (MMAP) is developing computer technologies to support mathematics learning by middle schoolers. We outline the premises underlying our approach to software design and describe three software environments and the mathematical activities they support. Two features stand out: (1) the computer environments are resources in a larger activity structure—the group-based project; and (2), the work students do inside the software environments helps generate students discourse and mathematical activities.

Keywords — Computer-based learning, collaborative group work, mathematics education.

1. Introduction

Computer technologies can be powerful tools for doing mathematical work; they can also be powerful tools for learning mathematics. They can perform complex and tedious computations, quickly graph and transform curves (Confrey and Smith, 1992; Schoenfeld, 1990), display multiple representations of a problem situation (Kaput, 1989; Pea, 1987), display empirical data (Rubin, 1994), and support dynamic visualization of geometric objects (Lampert, 1988; Olive, 1994). Mathematics educators and researchers are aware of the potential that computers can bring to the math learning enterprise and have developed many different kinds of software environments.

Curricular guidelines and research in mathematics education have recommended the development of classroom activities that focus on the conceptual aspects of mathematics and that support conversations as a context for improving conceptual learning in mathematics classrooms (NCTM, 1989). The charge is for deeper understandings of mathematical ideas and more collaborative processes in classrooms. The expectation is that freeing students from the tedium and procedural burden of excessive calculating or graphing will enable them to turn their attention to mathematical objects and concepts.

Student collaboration has also been proposed as useful for improving conceptual learning in mathematics classrooms. Group work is expected to encourage an environment in which students can "explore, formulate and test conjectures, prove generalizations, and discuss and apply the results of their investigations" (NCTM, 1989). Researchers have explored peer collaboration and mathematical discussions, as well as discussions between students while using software (Hooper and Smith, 1994; Moschkovich, 1993; Goldman, 1995).

We are committed to the development of computer technologies to support mathematics learning by middle- school students. We have been actively engaged in a research and development initiative for four years, the Middle-School Mathematics through Applications Project (MMAP).[1] While MMAP is not solely a technology development project, the development of computer-based environments is a key component of our work.

When we began our work, we considered many ideas about how computer technologies might help

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children be more successful at learning math. First and foremost was that any computer technologies we developed would have to be useful tools for meeting the learning needs of students who have been underserved by more traditional approaches to school math. Our theories and ideas about how children learn mathematics would inform design decisions and eventually become embodied in our software (Bowers, 1988). We wanted to create modeling and simulation environments that would encourage a collaborative kind of mathematics in the classroom. We wanted to test the possible roles that technologies might play in creating a more applications-based and collaborative version of school mathematics. Our belief that learning is a social activity meant that we wanted to create classroom environments where students would become equally engaged with each other and mathematics.

In this paper we tell a short story of how we conceive and design math projects and computer environments. The story highlights two important points about the reciprocity of the MMAP software environments: (1) the computer environments are interactional and mathematical resources in a larger activity structure—the group-based project; and (2) design work students do inside the simulation and modeling environments help to generate opportunities for mathematical activities and student discourse. We outline the premises embedded in our approach to design and describe three software environments and the kinds of mathematical engagement they support.

2. Environments for Collaborative Math Learning

Our view is that mathematics is crucial to everyday living and to current scientific practice. Hence, our materials are designed to reflect that view through a group-based applications approach to learning mathematics. Central to our applications project focus is the placing of students in design problems that require the use of mathematics concepts as tools for their solutions. By experiencing the utility of applying these concepts as tools, students have a chance to appreciate the power of the mathematics. The students can compare and deepen their evolving understanding and mastery of the tools-in-use.

Our charge is to design mathematics learning environments that integrate real-world problem solving, collaborative group work, and material resources that include computer-based tools. MMAP software must help us meet several goals, and our design and development work has evolved continually. From the start the process has been cyclical and iterative. The process relies on cycles consisting of four main activity components: design, prototyping, field testing, and analysis and redesign. The most characteristic feature of the design process is that it is heavily school-based. All development stages are informed by the real everyday conditions of middle school teachers, students and classrooms. MMAP team members observe and videotape in classrooms and interview teachers and students at each stage of the development process, first to validate application ideas, and then to test prototype designs against desired interaction with mathematics.

When we began development of our first software prototype, ArchiTech©, our criterion was that it had to pass a student engagement test and a math "yield" test. After one full year of prototyping and field testing the design environment for creating floor plans, we were able to settle on a design premise that met the engagement and math yield criterion. We settled on the idea that the computer environment and the activity environment needed to become symbiotic; one was only useful and engaging if it was totally interlocked with the other. This was a major departure from the ways we had seen other software for mathematics learning come into development. We do not develop "mathematics" software with some suggested activities for their use. We first decide on the kinds of interactions and collaborations we want students to have with mathematics, design activities to realize them, and finally, decide whether supports for the interactions are best left in the software or in the classroom activity structures.

These design decisions mean that our software environments are quite consciously not stand-alone in any sense of the term. To complete unit activities a group of students have to use some component of the software, and while using some part of the software, emergent classroom math activities are generated. Using the software is only satisfying in yielding the range of middle school mathematics we expect if the students are engaged in solving particular kinds of problems with corresponding constraints. The computer applications support designing solutions to these problems by providing multiple representations, levels of operation, and analytic opportunities.

Currently, there are three MMAP software environments. In each technology supported project, groups of students role-play adult occupations: architectural designers (using ArchiTech©), cryptographers and cryptanalysts (using Coding Toolbox©), or biologists and policy designers (using HabiTech©). Each individual plays a role in a group, and each group in class–wide activities. The goal is to create situations where the math can be helpful in solving a common problem, and student conversations and discussions help to bring about new mathematical understandings. The computer simulation tools allow students to immediately design solutions to their problem without getting bogged down in unnecessary technical details, computation, or symbolic forms. The environments give students access to multiple representations of their work and information about the different designs they create. The technology also helps students organize data in certain ways, structure their reportability, and use the data in explanations.

3. Three Software Environments for Engaging Students in Math Learning

In *The Antarctica Project* unit students take on the role of architectural designers who are creating a research station for a scientific expedition to Antarctica. Students use ArchiTech© to create floor plans and retrieve information on their structures' heating and building costs. Students have opportunities to develop and apply measurement and scale concepts. They work with independent and dependent variables and controlling variables situations through math opportunities which utilize hands–on experiences with the software.

With the ArchiTech© environment the group's floor plan becomes a conversation piece in two ways. First, because the group shares a design, their design decisions need to be negotiated, made explicit and justified. These aspects of design are also supported by the curriculum and the classroom activities for this unit. Second, students can make conjectures about how changing a variable, such as insulation, might affect the cost to heat a structure. They can then test these conjectures by changing the value of insulation in their design and seeing how other quantities are affected by this change.

In the *LifeLines* unit, students work as population-biologist advisors to policy makers regarding wildlife issues. Students use HabiTech© to create and run dynamic mathematical models of wildlife interactions and graph or chart changes in those interactions over time. They translate from verbal descriptions of animal behavior to mathematical descriptions and create relationships among variables such as animal birth rates and death rates. Students explore how different kinds of functions produce different patterns of growth (linear, logistical, and sinusoidal).

In the HabiTech© environment, students experience the connection between two representations, natural language and algebra, as they make and test conjectures about different rates of birth and death. They also alternate between tabular, algebraic, and graphical representations of different relationships.

In the *Codes Inc.* unit, students take on the role of cryptographers and cryptanalysts, designing and analyzing codes for various clients. Using the Coding Toolbox©, with its three different tools, students work with patterns and algebraic functions in various representations, use tables, verbal rules and graphs to represent number patterns, and are able to see and use both linear and non–linear functions. The Matrix Tool lets students work with transposition ciphers, rearranging the letters in a message by using a matrix and using number theory (factors, primes and multiples) to construct and analyze these codes. The Matrix Tool requires students to use patterns based on factors and remainders. The Function Tool lets students use a subset of algebraic expressions with a single variable to create replacement ciphers, where each letter in the alphabet is assigned a symbol using functions. The Analysis Tool, useful for "breaking" codes, requires that students look for and use patterns both in the frequency of symbols and letters and in the code key table.

These environments provide some of the usual types of support that one considered useful for software environments in mathematics. For example, while using Coding Toolbox© students use the connections between the graphical and algebraic representations of functions to decide whether the equation for a code is a first or higher degree equation. Most unusually, these environments are designed to support early access to some mathematical concepts. For example, the Coding Toolbox© environment can be useful without students generating their own symbolic forms or graphs. It thus supports the development of qualitative understandings of functions and the connections between two representations. These serve as an entry point to a conceptual view of functions while being used in the service of solving a larger problem. Likewise, HabiTech© allows the creation of models based on either natural language or symbolic expressions, thus allowing earlier entry into the processes of mathematical modeling.

4. Summary

Our goal is to develop technologies that become seamless components of the classroom activities. We have strong ideas about what we want computer technologies to do for middle-school aged children and even stronger ideas about the kind of collaborative math learning we want to make possible. Our orienting criteria are that the computer-based environments need to:

- be easy to use and invite all students to engage in mathematical activities, regardless of past school math history or level of mathematical sophistication;
- reflect the mathematics standards and frameworks by supporting collaborative learning, complex problem solving, understanding and use of multiple representations, analysis, explanations, etc.; and,
- bridge the gap for students between school math and the real world where mathematics is useful.

Today, three software environments are up, running, and robust enough to be field tested in a variety of classrooms across the country. Our research team has observed and documented in field notes and videotape over 300 hours of collaborative work, software use and mathematics conversations by middle schoolers involved in MMAP. One focus of the project's research program is to examine if the environments support conceptual learning and collaboration among students.

To date, two findings seem promising. The environments generate and support conversations between students. These conversations can serve as the sites for negotiating and transforming students' descriptions of mathematical situations (Moschkovich, 1993). The students' computer- generated designs and supporting data serve as the referents for conversations, provide a medium in which students can make, record, and evaluate competing conjectures, and provide entry points into mathematical topics and teachable moments.

The environments also shift the locus of control in the design work from the teacher to the students. Each environment allows students to create their own design. Whether they are being questioned about their progress or about the features of the design, the students must explain their work to the teacher before next steps are negotiated. The responsibility for explanation lies with the students even when they are seeking the help of their teachers. They must "bring the teacher up to speed" in order to make it possible for the teacher to help them.

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Support for Workspace Awareness in Educational Groupware

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Abstract

Real-time educational groupware systems allow physically separated learners to work together in a shared virtual workspace at the same time. These systems do not yet approach the interaction richness of a face-to-face learning situation. In particular, one element poorly supported is *workspace awareness*: the up-to-the-minute knowledge a student requires about other students' interactions with the shared workspace. This awareness is essential if students are to learn and work together effectively. We present a framework of several types of awareness required by students in a collaborative learning situation, including their social, task, concept and workspace awareness. We then concentrate on workspace awareness, and describe how particular awareness requirements of students in group learning situations depend on the closeness of their tasks, and whether they are sharing the same view or have separate views into the workspace. From these requirements, we have prototyped several *awareness widgets* for educational groupware. These widgets help learners maintain awareness of other learners' locations when their views are separated, of other learners' activities in shared and separate view situations, and of other learners' past activities.

Keywords — awareness, widgets, groupware toolkits.

1. Introduction

Researchers in computer-supported collaborative learning (CSCL) attempt to understand and provide technological support for cooperative and collaborative learning [e.g. 17, 24, 21]. Within CSCL, one area of interest is groupware for real time distributed learning. These systems let geographically separate learners collaborate at the same time in a shared virtual *workspace*, a software environment containing learning and work artifacts that can be viewed and manipulated by anyone in the group; audio and perhaps video links are typically available as well. Educational groupware is becoming viable as local and wide area networks are put into place, which will allow its use both in networked classrooms and in distance learning.

Educational groupware does not yet provide the richness of face-to-face interaction. If such systems are to foster learning within a context of interaction, as has been advocated by educational theorists [e.g., 5, 3, 18], they must support the existing practices and processes of group learning. One practice critical to collaborative learning but not well supported in current educational groupware is *workspace awareness,* the up-to-the-minute knowledge a student needs about other students' interactions with the shared workspace [13]. Collaborating learners maintain this awareness by tracking information such as other learners' locations in the shared workspace, their actions, the interaction history, and their intentions. Workspace awareness is necessary for effective collaborative work, but also plays an integral part in how well an environment creates opportunities for collaborative learning.

This paper describes our investigation into the awareness requirements of collaborative learning, and specifically, how workspace awareness can be supported in groupware interfaces. Section 2 presents a framework for organizing the awareness requirements of a collaborative learning situation. Section 3 describes workspace awareness in more detail, and Section 4 describes our initial work in supporting workspace awareness through innovative interface components.

2. A Framework of Awareness

We have created a framework of awareness in collaborative learning in order to discuss the types of awareness that are used in a collaborative experience. We briefly explore the involvement of, and awareness requirements for the curriculum designer, teacher, evaluator and student in a successful collaborative ac-

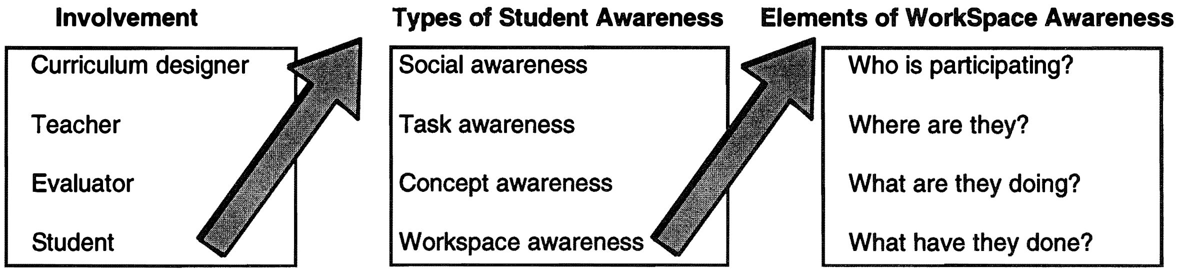

Figure 1. Framework of awareness in collaborative learning.

tivity. We then focus on types of student awareness which include: social, task, concept and workspace awareness. Workspace awareness in CSCL then becomes the focus of Sections 3 and 4. The skeleton of the framework, shown in Figure 1, creates a context for our later discussion of workspace awareness.

The success of a collaborative learning experience depends on the informed involvement of curriculum designer, teacher, evaluator, and students (Figure 1, left). The curriculum designer is responsible for the development of the activity and must apply the pedagogy of collaborative learning [e.g., 4, 30]. In addition, the curriculum designer must be aware of the objectives of the activity and must design the collaborative experience to support these objectives. The teacher is responsible for facilitating the activity and must work within the constraints of the group they are working with. The teacher must be aware of what the students are doing in the activity in order to help the students work towards the successful completion of the task. The evaluator is responsible for the evaluation of the process and must monitor the interactions that take place during the activity and must be aware of the outcome of the task. The students are responsible for working together to complete the collaborative task, and as part of the collaboration they must be aware of what is going on around them. Although every role and type of awareness in the process is important, the role of the student and the types of awareness they must have for a successful collaboration are the focus of the following discussion.

Goldman [12] identifies three types of student interaction: social, task, and conceptual. For each kind of interaction there is a corresponding type of awareness; in addition we add another type of awareness called workspace awareness (Figure 1, middle). *Social awareness* is the awareness that students have about the social connections within the group. *Task awareness* is the awareness of how the task will be completed. *Concept awareness* is the awareness of how a particular activity or piece of knowledge fits into the student's existing knowledge. Finally *workspace awareness* is the up-to-the-minute knowledge about other students' interactions with the shared workspace, suche as where other students are working, what they are doing, and what they have already done in the workspace. The questions in Table 1, organized into the categories described above, are examples of what students consider during the collaborative activity in order to be aware of what is happening in the group as they work on their task.

As suggested by the questions in Table 1, social awareness is inter-personal and perhaps best supported implicitly. For example, audio/video conferencing and media spaces [e.g., 6] can create communication opportunities that let people exchange necessary information with each other and negotiate their roles. Support for both task and concept awareness has been considered in cooperative learning [e.g., 16] and CSCL research; this support often provides explicit structures

Table 1. Types of Student Awareness.

Social awareness	• What should I expect from other members of this group? • How will I interact with this group? • What role will I take in this group? • What roles will the other members of the group assume?
Task awareness	• What do I know about this topic and the structure of the task? • What do others know about this topic and task? • What steps must we take to complete the task? • How will the outcome be evaluated? • What tools/materials are needed to complete the task? • How much time is required? How much time is available?
Concept awareness	• How does this task fit into what I already know about the concept? • What else do I need to find out about this topic? • Do I need to revise any of my current ideas in light of this new information? • Can I create a hypothesis from my current knowledge to predict the task outcome?
Workspace awareness	• What are the other members of the group doing to complete the task? • Where are they ? • What are they doing? • What have they already done? • What will they do next? • How can I help other students to complete the project?

that students can use as scaffolds to assist them with organization or to help them stay focused on the learning tasks [30]. For example, cooperative learning assigns explicit roles to students and provides a clear outline of how the task is to be completed. In CSCL, knowledge-building environments such as CSILE [28] and CoVis' collaboratory notebook [20] provide structured message capabilities that guide students through the steps of a learning dialogue. Support for workspace awareness can be provided in part by *feedthrough* of what others are doing in the shared workspace. Although social, task, and concept awareness are important to the success of a collaborative learning experience, we now consider workspace awareness in more detail.

3. Workspace Awareness

The rest of this paper deals specifically with workspace awareness. This section describes workspace awareness in more detail, and presents a third part of the framework that organizes group learning situations in terms of task and view proximity.

3.1 Workspace awareness in collaborative learning

As already mentioned, a student requires up-to-the-minute knowledge about other students' interactions with the shared workspace if they are to learn and work together effectively. This awareness is important in collaborative learning for two reasons. First, it reduces the overhead of working together, allowing learners to interact more naturally and more effectively. Second, it enables learners to engage in the practices that allow collaborative learning to occur.

As an example of how workspace awareness allows groups to be more effective, consider two learners who are reconstructing a poem given to them as individual, mixed-up lines. Each person maintains an awareness of where in the text the other is working, what they are doing, and what their intentions may be. Learner A may begin by picking out two lines that end with a certain rhyme. Learner B can ascertain A's activity by watching her work, even though she has not explicitly stated her chosen task. If B during the course of his own tasks comes across another line with the same rhyme, he can pick it out and give it to A, thereby assisting with her part of the task. This moment of collaborative effort is made possible because of workspace awareness, and though small, will be joined by many other similar moments of opportunistic collaboration. Taken together, these actions allow a group to be significantly more effective than an individual.

Workspace awareness also allows students to take advantage of the opportunities for interaction that make collaboration a valuable way to learn. In a collaborative learning situation, people may learn in a number of ways, such as:

- modelling the practices and skills of a more knowledgeable peer [e.g., 11, 8];
- identifying and resolving differences between conflicting ideas and theories [e.g., 9, 19];
- peer teaching, where one student assists or instructs another when appropriate [e.g., 31]; and
- constructing new shared meanings practices [23, 27].

Each of these mechanisms depends upon learners having a clear understanding of others' interactions with the workspace. For one learner to model another, they must be able to perceive the details of what others are doing. For one learner to propose a competing hypothesis at a point when it will be immediately relevant, they must know what other people's activities and intentions are. Peer teaching is similarly dependent upon knowing what another learner is working on and what they have already attempted, and building shared knowledge demands that a group understand what each other are doing and have done. Although the learning in a collaborative situation is dependent upon many factors, such as verbal interaction [22], it is the awareness of others and their activities that allows learners to initiate meaningful interaction at appropriate and opportune times.

3.2 Workspace proximity and workspace awareness

Another mechanism of collaborative learning that workspace awareness makes possible is to use the workspace artifacts as *conversational props* [2] that support learning dialogues. When the objects being discussed are visible to both learners, they can point and gesture to make clear the referents of their comments (called *deixis*), something that is difficult using language alone [3]. In addition, visible objects can act as a notational system [29] that extends the range and sophistication of concepts that the learners can discuss.

Although workspace awareness is often taken for granted in face-to-face collaborative learning situations, current groupware systems provide only a small amount of the information that students need to maintain it. We have been investigating how workspace awareness works in face-to-face situations, and how it can be supported in groupware applications. Our goal is to create real-time educational groupware that allows much of the same kinds of interaction, opportunities for collaboration, and opportunities for learning that are possible in a face-to-face situation.

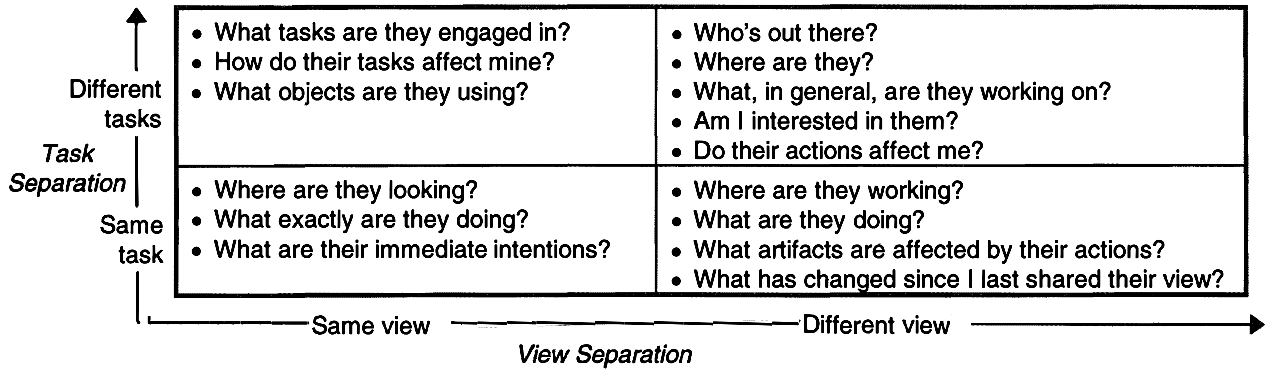

Figure 2. View and task proximity in collaborative situations.

The last part of our framework, shown in Figure 2, is a step towards this goal; it organizes group situations in a way that allows us to examine the specific mechanisms and information sources that people use to maintain workspace awareness. This organization considers two dimensions of group activity that involve the distance between learners: *view separation* and *task separation*. View separation is how closely group members share their views of the workspace. Learners will either be looking at the same set of objects or at different objects at any one time. Task separation considers how closely learners share activities. Although we assume they will be sharing an overall goal, learners may complete various low-level tasks as a group or as individuals. Figure 2 shows these two dimensions of group activity and, for each major area within the space, lists some of the workspace awareness questions that learners may need to answer.

Some of the collaborative learning situations defined in Figure 2 are outlined in the following section; we also describe our early investigations into supporting workspace awareness through groupware interfaces.

4. Widgets for Workspace Awareness

We are currently building general and reusable groupware interface widgets as part of GroupKit [25, 26], a groupware toolkit that streamlines the construction of multi-user applications. These widgets, designed from the framework described above, have been used in prototype groupware applications for exploring the issues involved in supporting workspace awareness. Educational groupware systems built with GroupKit are designed for multiple students in different locations, each with their own computer that is connected via a network. GroupKit supports interaction within a computational workspace, but does not directly supply audio or video communication; we assume that these channels will be provided through other technology.

The following sections describe three types of collaborative learning situations derived from Figure 2, bottom half: same task and same view; same task and different views; and same task with a mixed focus between views, where learners shift their attention between their individual and shared work. Within each situation, we describe GroupKit widgets and prototypes that support the maintenance of workspace awareness.

4.1 Same task, same view situations

In some collaborative learning situations, students work on the same low-level tasks, and focus on a small set of common objects. These situations involve close interaction and require awareness of the precise location and exact actions of other learners. For example, group creative writing involves partners who discuss and collaborate on each word and phrase of a poem; they need to know the exact context in which to interpret the other's comments and contributions. Peer editing is similar, where two students carry on a detailed discussion about a piece of writing. This activity illustrates the importance of supporting gestural communication—the two learners will use their text as a conversational prop, indicating pieces of text and possible changes by pointing and gesturing. Another example involves exploration and problem-solving in a physics microworld, where students work at the same task level, take part in each decision and action, and discuss the changes they see [7].

Same-view groupware systems (called strict 'what you see is what I see' or *strict WYSIWIS* [32]) must provide precise cues as to another learner's location and activity. GroupKit provides these cues in two ways. First, a designer is given control over how closely the screen actions are linked. For example, a shared drawing program might transmit the intermediate positions of an object as a student is moving it, or perhaps only transmit its new position after the move is completed. In a same-task same-view groupware appli-

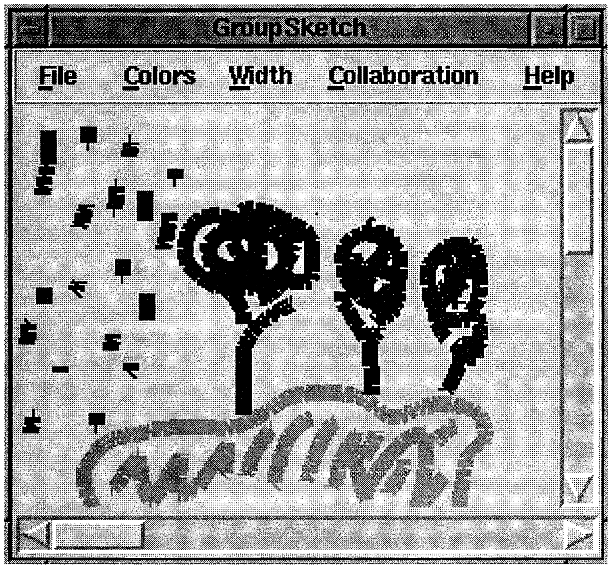

Figure 3. Multiple cursors in a group sketchpad

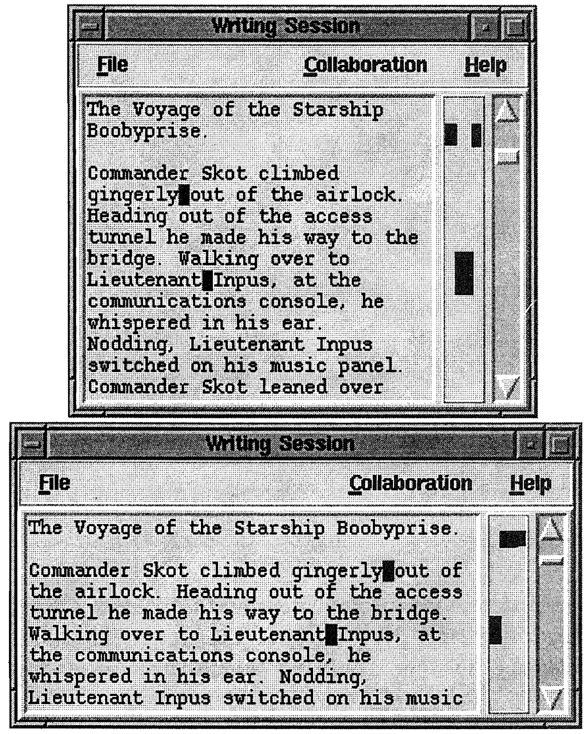

Figure 4. Two student's views into a peer writing session, showing semantic cursors and multi-user scroll bars.

cation, we believe fine-grained screen linking gives learners a greater awareness of immediate changes to the workspace.

Multiple cursors [14] are a second means for supporting fine-grained awareness of location and activity in GroupKit. These show each person's mouse cursor and their movements displayed on every learner's screen. Multiple cursors allow gestural communication and give visual cues to a person's activity and intentions. Figure 3, for example, shows two students using a groupware sketchpad to present a weather cycle; their cursors are the two arrows labelled with their names.

We have extended the idea of multiple cursors for situations where people see the same objects but with different presentations. The problem is that reproducing the literal movements of each person's mouse cursor across the displays will not show their actual position in the text. To address this problem, we have prototyped a *semantic cursor* that indicates the logical location of a person's cursor in the text rather than its screen position. For example, Figure 4 shows windows belonging to two students involved in a creative writing session; although both their views of their story begin at the same place, their text formatting differs. In the top window, the student's mouse cursor points to some text; this position is displayed as a semantic cursor in the bottom window by highlighting the letter (the space between 'gingerly' and 'out') rather than the actual screen location.

4.2 Same task, different view situations

Some learning situations involve coordinated action that occurs in different areas of the workspace. This kind of interaction can be seen when learners create a poster or collage: the learners are no longer making group decisions about each word or figure in the poster, and they may be working on different parts of the page. However, a sense of awareness about the others' activities is needed for coordination of effort and for making overall decisions. Another situation involves literature students who have the task of finding imagery of evil in Macbeth; each student looks for images of a different theme (blood, darkness, reversal, or decay). The students are working toward the same goal, and will need to keep track of each others' activities and progress, but they will all be looking at different parts of the play at any one time. A third example from our experience is that of social-studies students constructing a timeline to represent events in the history of a country. Since the timeline will be long, students will often have different views onto the document. Again, they will still need information about where others are working, perhaps to offer additional information or to see what remains to be completed in the task.

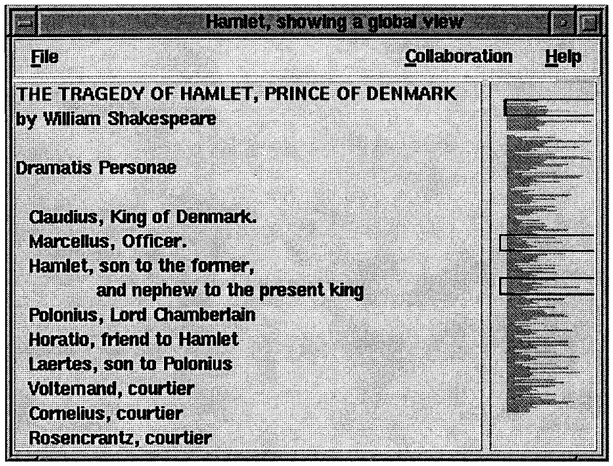

Figure 5. Global view of 3 student's locations in *Hamlet.*

Different views into a common workspace (called *relaxed WYSIWIS* [32]) imply that the requirements for workspace awareness will be coarser than in a strict WYSIWIS situation. Awareness of fine-grained actions like the movement of someone's pointer may be less important, but awareness of location with respect to the entire document, and awareness of activities at a higher level, are more important. However, there are also cases where learners may need some kinds of detailed information about others' activities, such as the kind of information that is gathered through peripheral vision or hearing in a face-to-face situation.

We have designed both a multi-user scrollbar and a global display widget in GroupKit to provide information about both location and activity in relaxed WYSIWIS systems. Figure 4 shows the multi-user scrollbar and how it supports workspace awareness by pinpointing other learners' relative locations within the document. The right-most control acts like a standard scrollbar, and lets each student manipulate their own view. To its left are several uniquely-colored vertical bars showing the relative viewport of all three learners in this session. In this case, Figure 4 shows two learners with aligned views (whose windows are both shown), and a third learner viewing text near the end of the document. The position and size of each bar is continuously updated as learners scroll through the document or change their window size. If a learner wishes to match their view with someone else's, they need only drag their scroller until it is level with the other's indicator bar.

The global view display, illustrated in Figure 5, is a richer version of the multi-user scrollbar. It shows a miniature of the entire document (the right window), overlaid with colored boxes that represent the viewports of all students into the document. The miniature provides structural cues about the document that help the student understand where their collaborators are working and what they are doing. The colored viewport boxes are also active interface objects: a student scrolls to a new location by dragging their box with the mouse, and the text window on the left is updated accordingly. In the figure, for example, the local student is reading the beginning of Hamlet, and her box is drawn at the top of the global view. Two other students are further on in the text. As in the multi-user scrollbar, she can make her view congruent with another student's view by dragging her box to the same level as the other's box.

Supporting fine-grained awareness of activity in different-view situations is more difficult than when learners can see the same objects, since they can no longer see the other person's cursor or how the objects are being changed. Limitations on screen space discourage the simple solution of showing complete duplicates of every student's view. Instead, we have prototyped a 'what you see is what I do' (*WYSIWID*) display. This widget shows only the immediate context around another learner's cursor, which is a subset of their view. This is illustrated in Figure 6, where a person sees not only their main view (left side), but also part of another student's view (top right corner). The remote view is always centered around the other student's cursor; rather than showing cursor movement, the background is panned instead. Since most actions in graphical applications involve the mouse cursor, this local-view display can show in detail what others are doing, yet consume only modest screen real estate.

4.3 Same task, mixed focus situation

A third kind of collaboration flips between same-view and different-view situations. We call this kind of interaction *mixed focus collaboration*: individual and shared activities within the workspace are interleaved, and learners periodically shift their attention back and forth between separate and shared views of the workspace. In practice, many collaborative learning situations will have elements of mixed focus collaboration. In the examples described so far, the poem reconstruction, the collaborative poster, and the group effort in finding imagery in *Macbeth* would all involve periods of individual and shared activity.

While mixed focus collaboration can be partially supported by the techniques discussed in the previous two sections, it presents additional requirements for workspace awareness. In particular, a learner may need to bring oneself up to date on what the other person has been doing—the changes they have made and where they have been—before rejoining their view and starting a period of shared work.

Existing techniques such as adding change bars to a document or calculating the difference between two versions ('diffing') can only provide some of this information, and usually only for text documents. We have designed a few widgets to investigate awareness of a group's recent actions. For example, to support awareness of where other learners have been working, we have prototyped a history mechanism to a global view display, as shown in Figure 7. In addition to showing another learner's current viewport, the widget tracks their location over time. Moving the slider at the bottom of the window plays back the movement of another person's viewport (displayed as a moving outline rectangle), and also indicates where they stopped for a while (shown as a filled rectangle).

5. Related Work and Further Research

Educational groupware draws on work done in the field of computer-supported cooperative work [10]; several CSCW projects have considered the issues involved in creating real-time distributed systems, and some have touched on the concept of workspace awareness. For example, the multi-user scrollbar and a global-view device called a gestalt viewer were first seen in the SASSE text editor [1]; other systems have used tools like activity indicators [32, 10] to keep people informed. One branch of CSCW research that has promise for supporting both social and workspace awareness looks at mixing video signals of learner's hands or faces together with a computational representation of the shared workspace [15].

Our investigations into support for workspace awareness will continue in several directions. We plan to conduct observational experiments to gather data about what mechanisms people use to maintain workspace awareness in particular situations like mixed focus collaboration. From this knowledge, we will

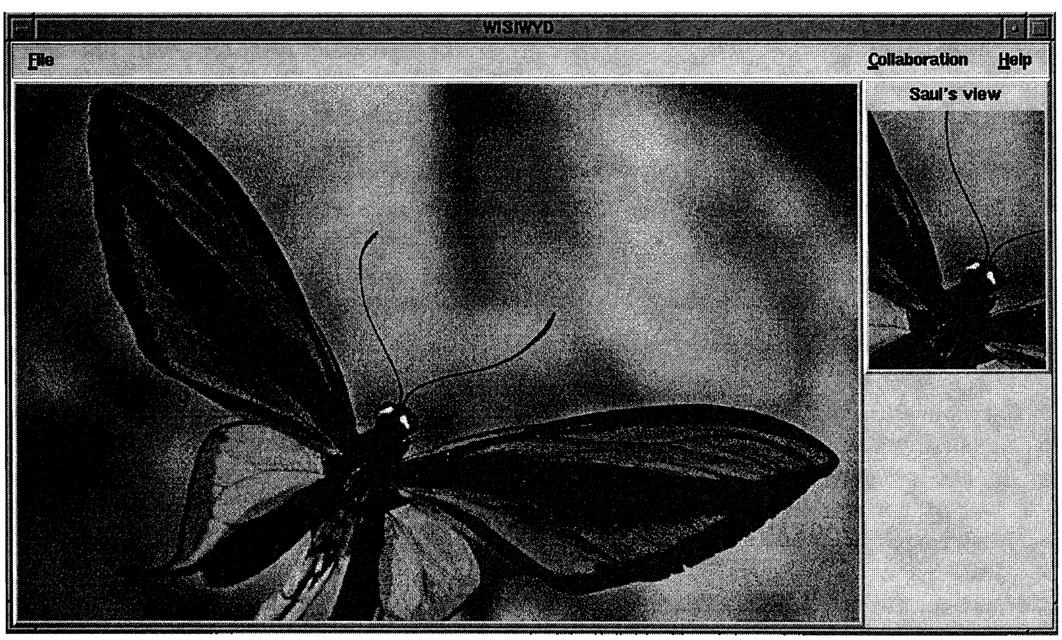

Figure 6. A 'what you see is what I do' widget.

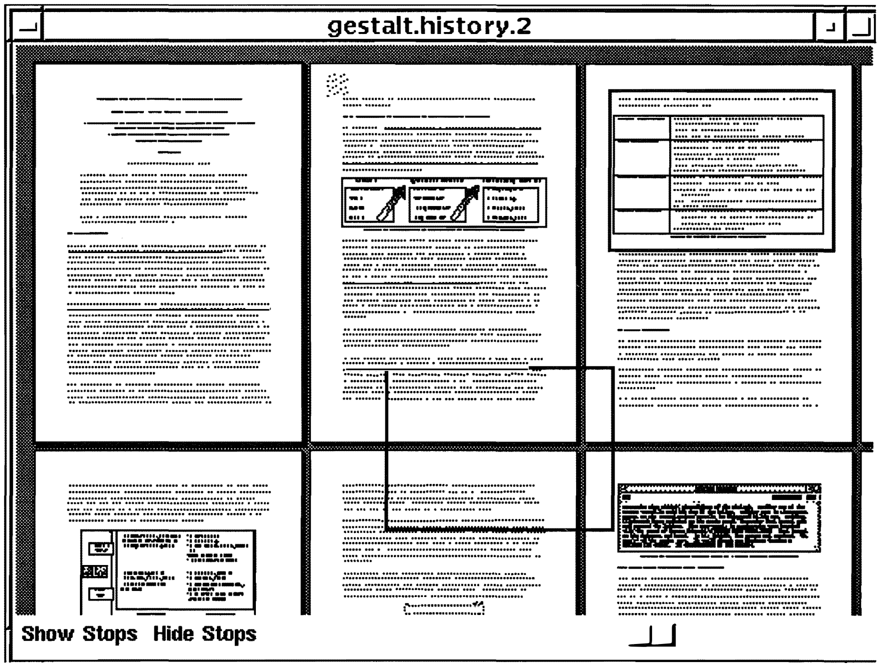

Figure 7. A global view with history.

form design principles for new groupware widgets. As well, we are identifying overall issues that affect the design and implementation of these techniques, including:

- the trade-off between being well informed about other learners' activities but being distracted by that information from their individual tasks;
- allowing learners to exert some control over the awareness information that others receive about them;
- whether we can go beyond existing face to face practices, and create new awareness mechanisms that augment, rather than just replace, what people normally expect.

6. Conclusion

This paper has outlined a framework that sets workspace awareness in a context of awareness requirements for collaborative learning. We presented a way to organize collaborative situations in terms of task and view separation, and introduced several interface components that support the maintenance of workspace awareness in educational groupware. The components are useful for same view situations, for different view situations, and also for mixed focus interaction.

Acknowledgments.

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Availability and Contact Information

GroupKit is available via anonymous ftp, and a world wide web page documents the system:

site:	ftp.cpsc.ucalgary.ca
directory:	pub/projects/grouplab/software
http:	http://www.cpsc.ucalgary.ca/projects/ grouplab/home.html

Contact authors at [gutwin, saul]@cpsc.ucalgary.ca and gstark@cbe.ab.ca.

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Collaborative Support for Learning in Complex Domains

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Abstract

Engineering is a complex domain to learn. CaMILE (Collaborative and Multimedia Interactive Learning Environment) aims to facilitate engineering students' learning. CaMILE builds on Cognitive Flexibility theory [14, 15] in a CSILE-like structure [10, 11] through which students share multiple media and collaborate to develop understanding across diverse perspectives. CaMILE includes a collaborative NoteBase, a hypermedia database with guides, and an electronic book format. We believe that CaMILE supports students' engineering activities, but a cultural shift is required for CaMILE to effectively support students' learning.

Keywords — Collaboration software, multimedia, engineering education.

1. Introduction

Engineering is a classic example of (a) a design domain [13] which implies a set of problems for learning and (b) a complex domain in which it is difficult to learn and perform [15]. Learning engineering means developing understanding in a wide variety of conceptual domains (e.g., physics, behavior of materials, mathematics) while also developing expertise in problem understanding, problem-solving, and integrating diverse conceptual domains [12]. Adding to this already large load, engineering educators are now calling for more relevance of educational programs to actual practice – for example, emphasizing collaboration skills because of the increased use of engineering teams in the workplace [1, 2, 7].

We have been working with two different engineering curricula at Georgia Tech (Sustainable Development and Mechanical Engineering) to develop technology to support learning and doing of engineering students. We draw a set of criteria for technology that can facilitate learning in complex domains from the work by Rand Spiro et al. on Cognitive Flexibility theory [14, 15]. Our goal was to meet those criteria but with specific support for learning collaboration skills. Our model for collaboration support was Scardamalia and Bereiter's CSILE [10, 11].

We have designed and implemented a learning environment called *CaMILE (Collaborative and Multimedia Interactive Learning Environment)* [4]. In CaMILE, students create multimedia compositions and share them in a discussion that can draw upon diverse perspectives. CaMILE consists of:

- A collaborative NoteBase where students discuss topics and integrate diverse media;
- A MediaBase where multimedia documents (text linked to multiple media) are provided along paths featuring anthropomorphic *guides* [8, 9]; and
- An Electronic Book format for making text resources easily available, annotated, and integrated into the NoteBase.

CaMILE was first used in the 1994-1995 academic year in a Mechanical Engineering course on design [5, 16] and in a course sequence on Sustainable Development [17]. In this paper, we describe CaMILE and its first year of use. While students made frequent use of CaMILE in support of their engineering activities, we see a need to change culture for enhanced learning.

2. Description of CaMILE

We identify three critical kinds of supports for student learning and how CaMILE addresses each based on the theoretical work we identified:

- *Support for reflection:* The collaborative NoteBase enables students to take an active role in discussions and in integrating diverse media. In addition, the NoteBase provides support for reflecting on the collaboration.

- *Support exploration of multiple perspectives:* The MediaBase provides *guides* which support different perspectives in a domain. For example, in a MediaBase on sustainable development, guides may represent the perspectives of economists, ecologists, and bankers or of developing versus developed nations.

- *Support integrated use of multiple resources:* All of the three subcomponents of CaMILE (NoteBase, MediaBase, and Electronic Book format) support links to a variety of media. For example, the NoteBase allows students to link to their discussions the following resources: any document on their computer (e.g., word-processing document, spreadsheet, drawing), sounds, graphics, digitized video, World-Wide Web pages, links to a particular node in the MediaBase or page in an Electronic Book, or a particular case in a case base (using the case-based design aid, ARCHIE [3]).

NoteBase: The core of CaMILE is a collaborative NoteBase where students can post multimedia notes in group discussions. The NoteBase uses a simple structure for multimedia composition called a Media Margin [6]. Student notes in the NoteBase contain text on the left two-thirds of the document and multimedia annotations appear as icons in the margin in the rightmost third. Students can directly manipulate the icons so that a media reference appears next to corresponding text.

Students are guided in their collaboration and are encouraged to reflect on their collaboration through a prompting mechanism based on CSILE's procedural facilitation [10, 11]. When students create a new note (Figure 1 left side), the NoteBase asks them to identify the *kind* of note that they are creating in terms of the contribution's role in the overall discussion (e.g., raising a *New Idea*, or making a *Rebuttal*, or asking a *Question*). Based on the kind of note selected, CaMILE then makes *suggestions* on productive things to say in this kind of note (Figure 1 right side). In this way, students are encouraged to reflect on their collaboration (i.e., what kind of statement are they trying to make?) and are given some structure and hints on how to conduct the collaboration.

MediaBase: The MediaBase encourages students to explore a topic in multiple media and guides them through alternative and often conflicting perspectives on a subject. In the MediaBase, a content expert has previously placed information into *nodes*, which are collections of text with multimedia annotations (similar to the notes in the NoteBase). These nodes are organized into collections called *paths*. Each path contains nodes that are related to a common topic or theme.

Students are guided in the MediaBase by the use of anthropomorphic agents called *guides*. A MediaBase guide presents a specific point of view on the presented data. Guides have been shown to help a student make sense of complex domains which can be approached from several different angles [8]. A guide presents an opinion on a given node, and points to a path, called an *agenda*, with more information about the guide's subject.

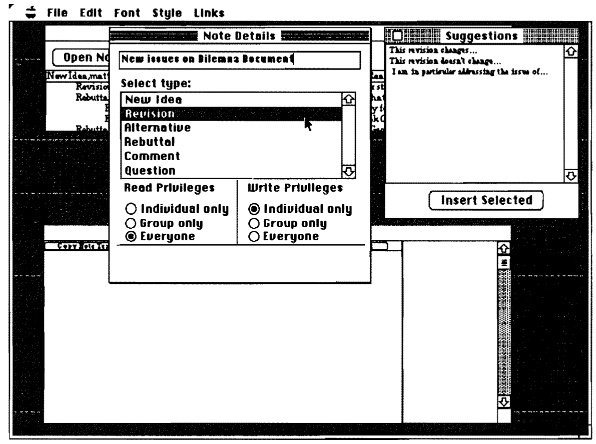

Figure 1. Prompts in CaMILE for kind of note and suggestions. A blank note appears at the bottom, and a discussion window listing related notes is visible at top left.

Electronic Books: A third component of CaMILE is an Electronic Book (*Ebook*) format. Much of the information available to undergraduates is in the form of text. While text provides information in a useful form, it cannot be easily linked with other related resources, commented upon, and shared. The CaMILE Ebook format supports linking of text to external multimedia resources, allows students to annotate the book in useful ways (e.g., writing notes in the margin, underlining key phrases, adding bookmarks, creating links from relevant phrases in the book to their own relevant material), and supports sharing of students' notes with one another. Students can link from a NoteBase discussion to an individual page in an EBook.

3. First Year of CaMILE Use

CaMILE has been used in three quarters in a Mechanical Engineering course and for one quarter in a Sustainable Development course.

- In the Mechanical Engineering class[1], students used CaMILE to discuss designs that they were developing in small groups (4-5 students) and to share material on those designs (e.g., drawings, design reports, timelines). Electronic book versions of the course texts were provided.

[1] During the first two quarters of use, students in the ME course volunteered to participate in a lab class in which CaMILE was used. During the Spring '95 quarter, a whole section of the course used CaMILE.

- In the Sustainable Development class, students used CaMILE to discuss cases being analyzed in lecture. A MediaBase of sustainable development cases is being created for this class, but was not available for this use.

Students used CaMILE to a much greater degree than we expected, particularly in the Mechanical Engineering course. For example,

- During Fall 1994, 14 students (plus a TA and teacher) generated over 400 notes in the ten week period, with over 100 links to external media. The majority of the links were to word-processing files (e.g., students sharing parts of a design report for comment), spreadsheet files, and design drawings. There were no links to EBooks at all.
- During Winter 1995, 7 students (plus a TA) generated over 200 notes with some 50 links to external media.

We can characterize the use of CaMILE as having two types:

- *Discussions on Assigned Topics:* Students were assigned topics to discuss using CaMILE to mediate the discussions, as a means of teaching students how to use CaMILE and where it could be useful. The discussions on assigned topics made use of the collaboration supports in CaMILE, but the quality of the discussion was relatively low – which was not surprising given the inauthentic nature of the use. What was the surprising in this kind of discussion was the students' relatively frequent use of the Media Margin to exchange files (e.g., word-processing documents typed at home without network access and posted on campus).

- *Discussions to Meet Goals:* These discussions were created by the students (most often protected as private to a group) for the purpose of meeting design goals: Agreeing on a design issue, exchanging materials for a design report, etc. Students in these discussions exchanged numerous files with one another, such as pieces of design reports or sketches. While this use was authentic and meaningful to the students, there was relatively little use of collaboration support (e.g., most notes were labeled *Comment*) and there was little discussion more than "Here's my report for review" and "Here's my revision."

4. Discussion

In general, our experience with CaMILE was different from the CSILE experience described by Scardamalia and Bereiter. While the software was designed to offer similar functionality, we did not see the enthusiastic use, carefully crafted arguments, and evidence for learning-through-collaboartion seen in the CSILE transcripts. Instead, we saw students using CaMILE as a virtual mailbox or group memory for sharing media of all sorts (documents, drawings, plans), but not as the collaborative knowledge-building activity that the CSILE people discuss. While such use suggests that CaMILE was valuable (based on frequency of use) to students in support of their engineering *doing*, CaMILE was not being seen as supportive of their *learning*. Thus, we argue that CaMILE is facilitating students in coping with the performance part of the complexity of the engineering domain, but we also believe that CaMILE can play a more significant role.

We believe that the difference between the CSILE experience and our own is a difference in terms of classroom culture and curriculum. CaMILE was used in relatively traditional settings with relatively traditional curricula, where the goal is to conduct engineering activity primarily and to learn from the activity secondarily. The value of *knowledge-building* that is so central to CSILE was not part of the dialectic in the classrooms where CaMILE was used.

Building knowledge for the sake of knowledge is not a value that can easily be instilled in an engineering curriculum. However, building knowledge so as to inform problem-solving or to create a group memory that includes arguments and differing perspectives are activities which can be valued. We might call such a perspective as *knowledge-building for action*[2]. Our future directions are to explore tighter integration of CaMILE and a value for knowledge-building for action with the culture and curricula of the engineering educators with whom we are working. Such a change in culture might encourage student use of CaMILE for reflection, exploration of multiple perspectives, and integration of diverse resources in the ways that we believe will lead to student learning.

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Technology Selection for Small-Group Collaborative Distance Learning

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Abstract

This paper reports on a case study that was carried out to investigate small-group collaborative learning through real-time remote communication technologies. The aim of the study was to develop insight into relationships between technology characteristics and collaborative learning that may help in making technology selection decisions. In this study, audio-conferencing plus a shared workspace led to equal task performance as audio-conferencing without such an additional tool. However, adding a shared workspace to an audio-conferencing setting may lead to less equal participation, and participants' reportings indicated it may have a negative effect on the amount of effort learners put into the task performance. In contrast, audio-conferencing only seems to lead to *more* effort by *all* participants. Effort may be positively related to mental processing and learning, which leads to hypothetical technology selection guidelines.

Keywords — Media selection, small-group learning, audio-conferencing, shared workspace.

1. Introduction

Collaborative distance learning is an emerging area of particular relevance to professional learning/working settings. We view collaborative distance learning as located in the intersection area of computer-supported collaborative learning (CSCL) and computer-supported cooperative work (CSCW) [1]. We try to build on tools, findings and perspectives from both areas, thereby pulling CSCL and CSCW together [4].

The present study is an exploratory investigation into relationships between collaborative distance learning processes and technology that may support these, hoping to obtain insights that help make technology selection decisions. Our perspective of collaborative distance learning processes is an educational one. We work from a social-constructivist assumption of the usefulness of small-group learning settings [e.g., 7], and aim at long-term higher-level learning. To this we apply telecommunications applications for real-time communication that have been a focus in CSCW research on supporting collaborative design. In particular, we focus on adding a 'shared workspace' [2, 10] on learners' computer screens to audio-conferencing. (The resulting tools and methods are somewhat similar to audio-conferencing and audio-graphics as have been used for years in distance education settings, but their use --for true collaboration, not for instruction-- and thus their design is different.)

Two theoretical notions guide us. The first is from McGrath and Hollingshead [5, 6] who suggested a task/media fit hypothesis: the more complex the task in terms of interdependency of participants, the higher the information richness provided by the technology should be. The second notion is Salomon's [8] 'amount of invested mental effort'. Salomon suggested that a learner invests more mental effort in doing a task through a certain medium if s/he thinks this is difficult (but within a feasible range), and that this extra effort may lead to more learning.

2. Research Questions

In the context of two technological configurations that may support collaborative distance learning: audio-conferencing, and audio-conferencing with a shared workspace, we asked the following descriptive/comparative and interpretive questions:

- Which collaborative learning processes occur using the different technologies, with what effectiveness; are there differences?
- How may potential differences be related to characteristics of the technologies that were used?

3. Method

A multiple-case study was carried out within a simulated setting. Three mixed-sex groups of three advanced masters students of our faculty, all used to small-group learning, were formed. These participants were offered a follow-up on a philosophy course they had followed, in the form of five case-work sessions. The learning objective was: being able to solve ethical problems that contain a moral dilemma in a rational manner. The participants were instructed that after a session each of them should be able to argue rationally why the decision was made as it was made. The task is a complex problem-solving and decision-making task. It is also a non-visual task: it can be performed by using words; sharing of graphics (in a shared workspace) is not a baseline requirement for communication.

In the first session the groups worked face-to-face; we included this configuration for baseline comparison. In the second session the participants communicated through audio-conferencing. In the third session they were provided with the same audio link plus a shared workspace on their computers' screens. The group editing program Aspects [3] was used, which provided simultaneous access by all to the same document in a shared drawing space. A few weeks later in the fourth and fifth session they worked through audio plus a shared workspace and audio-only, respectively. These sessions were added to enable detection of novelty effects. Each session started with a practice task; then the 'real' task was carried out. The session was concluded with a semi-structured group interview. All sessions were video-taped.

Collaborative-learning processes were analyzed using Stymne's [9] observational system. This system is based on the idea that collaborative learning is a process of solving many small problems of different types. Task performance was measured by applying five criteria for rational problem-solving and decision-making regarding moral dilemmas to the group work process as captured on video tape. The interpretive research question stated above was approached through the group interviews. The remainder of this paper describes results from analyzing the data from one of the three groups that were involved in the investigation.

4. Results

4.1. Collaborative learning

Collaborative learing in terms of Stymne's categories could be described as follows. The groups payed attention to 60 to 86 small problems per session. The majority of these were 'production' problems, that is direct task-cognitive problems (78 to 91% of total time; 40 to 67% of the total number of problem-solving sequences). So most of the time was spent on solving the ethical problem. 'Planning' problems took approximately 5% of the available time, or 12 to 23% of all problems. Other types of problem-solving sequences were rare or their appearance could be assigned to novelty effects. Non-task behaviour was very rare.

Task performance evaluations showed satisfactory results in each of the sessions (7.5 to 10 points on a maximum of 10 points). Performance appeared to decrease a little over time. This could be explained by the work approach of the group, which first took a 'step-by-step' approach to the problem, but later on loosened this approach and tried to find 'shortcuts'.

The coding according to Stymne's system and the task performance measurements did not yield differences in collaborative learning processes between the different configurations of technologies. The participants' perceptions and experiences as expressed during the group interviews allowed an insider's view, however, which complemented and refined this conclusion, and led to a more in-depth understanding of aspects relevant to the technology selection issue.

4.2. Technology

According to the participants' own perceptions quite different effects of working through the two technologies (audio-only and audio + shared workspace) led to the same level of task performance in the end. The keyword appears to be 'effort'.

In the audio-only sessions more effort seemed to be required of the participants to achieve the same results as in the face-to-face and audio + shared workspace sessions. This effort related to more explicit structuring of the task content, of the already agreed-on issues, and of the planning and progress that was needed to maintain a shared understanding and a shared focus. In the audio + shared workspace sessions this information was easily available to all and could even be pointed at, as it was written on each participant's computer screen. In the audio-only sessions participants had to take their own notes, and together maintain shared understandings and keep a shared focus only by talking to each other. The individual note-taking as well as the explicit structuring took time, but also required much attention and active involvement by all participants. This was unlike working through audio + shared workspace, where in general only one participant at a time was busy typing the group notes, and the other two could lean backwards and 'see it all happen before their eyes'. Instead, audio-only required a shared effort. This also facilitated a positive group feeling, which, together with the perception that each of the participants had been actively and equally been contributing to the task performance, led to a positive evaluation of the group's performance by each participant.

In the audio + shared workspace sessions writing group notes in the shared workspace facilitated mutual understandings of task content, agreed-on issues, and planning and progress; explicit structuring through speak was much less necessary. Keeping a shared focus was also facilitated by the working in the shared workspace. The visible group notes in the shared workspace gave the participants a more serious feeling of working on a shared product than in the audio-only sessions. This facilitated a positive group feeling. This group feeling was also influenced positively by the effect of telepresence that was created by seeing each other type, draw, or gesture (with the mouse pointer) in the shared workspace. Note-taking by only one participant at a time was sufficient; this utilization of effort and time was perceived efficient. However, it did not require all participants to be as actively involved as they were in the audio-only sessions. As a result, the participant who had written most of the group notes felt satisfied over the group's performance, as a result of her active involvement, the efficient task performance, and the feeling of having been part of a close group. The other two participants were satisfied over the group's performance because they had only put in as much effort as was necessarily required and had been working efficiently overall, and as they had felt a close group while working on a shared product. However, they were less satisfied over their own involvement in what they agreed was meant to be a learning task for all.

In sum, audio-only facilitated effective task performance through equal, active involvement and more effort by all. Audio + shared workspace enabled effectiveness without too much effort, by efficiency through inequal involvement.

5. Discussion

We conclude that collaborative distance learning can be as effective and satisfactory as face-to-face group learning. Deciding between audio-conferencing with or without a shared workspace, for non-visual tasks, seems a delicate issue however.

5.1. Task/media fit

McGrath and Hollingshead's [5, 6] task/media fit hypothesis is based on information richness in terms of social clues: the more complex the task in terms of interdependency of participants, the richer the information transmitted by the technology should be. Less complex tasks are for example brainstorming, which can be done collaboratively through text. More complex tasks involve coordination or conflict resolution, and require communication of (more) socially rich information such as evaluative and emotional messages in order to sufficiently reduce equivocality. Providing a group with a too 'lean' technology that would not be able to transmit sufficiently rich information to carry out the task would lead to effectiveness losses. A too rich medium, however, would distract the group by transmitting meaning that is non-essential for effective task performance, and thus lead to efficiency losses.

In our study both technologies used appeared to allow an effective fit. However, we did not find that adding a shared workspace led to efficiency losses. Most of the extra information richness the shared workspace offered, such as gesturing with the mouse pointer and visibility of the dynamics of others' editing on the screen, was found useful for coordination and keeping a shared focus. In the audio-only sessions, however, the participants were able to compensate for the lack of this richness. It seems that McGrath and Hollingshead's task/media fit hypothesis allows some 'freedom of movement' with respect to what is effective and efficient. Human adaptation capabilities and actual effort to compensate allow different patterns of factors to work equally effective and efficient.

5.2. Effort

Effort thus appears to be a key factor: audio-only requires more effort than audio plus a shared workspace to achieve the same level of task performance. Salomon [8] found that high perceived task/media demands led to high mental effort if they were within the range of perceived self-efficacy with regard to these demands. Audio-only was indeed perceived to be more difficult than audio + shared workspace; as the participants felt and appeared to be able to meet the requirements, they invested an appropriate extra amount of effort in their task performance.

Effort is often related to learning in that more effort would lead to deeper mental processing and thus to more learning [8]. From that we could recommend that for learning purposes audio-conferencing only should be preferred over audio plus a shared workspace (while the latter could be a better choice when task-related efficiency is merely aimed at). This recommendation should be restricted to learners with appropriate mental skills to compensate for the lack of information richness a shared workspace would offer.

6. Conclusion

From this study we conclude that collaborative learning over a distance can be as effective and satisfactory as face-to-face. For people with adequate listening and structuring skills in learning situations, audio-conferencing would be preferred over audio-conferencing with a shared workspace, because it requires and stimulates more mental processing.

The insights gained in this study allow us to speculate about a refinement of McGrath and Hollingshead's [5, 6] task/media fit hypothesis, using Salomon's [8] 'amount of invested mental effort' concept: mental effort allows some degree of freedom in task/media fit. This leads us to the following hypotheses with regard to providing media richness for learning:

- If you have to apply extra mental processing to handle 'noise', then less media is better.

- If you can compensate with your brain, then, with regard to mental processing, less media is better.

- If you cannot compensate with your brain, then more media is better.

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Listserver Communication: The Discourse of Community-Building

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Abstract

The purpose of this paper is to identify some of the characteristics of community-building discourse: the language forms that mediate the creation and nurturance of community in a Listserver context of communication; and the functions of this sort of action. Findings are derived from a three year ethnographic study of an international, 400 member group of academics who communicated with each other using ListServer technology on ten, subsequently five electronic mailing lists. Using Soviet Activity Theory and a Conversation for Action discursive model of communication to make sense of the *flow* of on-line communication, three recurrent patterns of communicative activity were identified as constitutive, though irreducible, to what was termed *electronic academia.* These patterns of communication were referred to as academic, administrative and community-building action, one of which is succinctly illustrated and discussed here. Characteristic features of community-building discourse selectively included here are naming the community; and civil language uses (i.e. warm and playful; grateful and positive uses). Functions of community-building action briefly presented are growth and continuity. Together, mediating functions and features of community-building are seen as foundation for productivity and conceptual change.

Keywords — Community-building, CmC (Computer-mediated Communication), collaborative learning, conceptual change, discourse processes, e-mail, ListServer technology, networks, telecommunications.

1. Background

This study builds both theoretically and methodologically on a number of pioneering studies of CmC (Computer Mediated Communication). Theoretically it builds on studies that have taken CmC as an object of inquiry (e.g.; Black et. al, 1983; Duranti, 1986). Methodologically, it builds on studies that have taken an ethnographic approach to the study of this phenomenon (Murray, 1991). This study is different, however, in at least one important way. It is different because the starting point is no longer the same as it was ten years ago. Ten years ago, the study of CmC needed to be constructed as an object of inquiry in its own right. CmC researchers were motivated to identify both the linguistic (Ferrara et. al, 1991; Murray, 1991a; Wilkins, 1991) and psycho-social features (Keisler et.al, 1984) proper to CmC; different from and common to both oral-aural and written modes of communication. With hindsight, and the current popular explosion of telecommunication usage (Calcari, 1994; Quaterman, 1994;) , I have taken for granted these important concerns (i.e.; that CmC exists as a phenomenon both different and similar to other forms of communication) as well as the answers found to these questions. I was motivated by a desire to make sense of massive volumes of occurring CmC communication (e.g.; "the size of Montana" , Swaine, 1995) , and in particular what is accomplished by such forms of communication in a small domain of the Cyberworld (i.e.; what an international group of academic users are doing-in-the-world via CmC). Finally, because ListServer usage offers a world that comes to life exclusively in language use, I was motivated to explore the relationship between language use and activity; the nature of this micro-world; how it is that it is created; by what means; for what purposes; and to what ends.

2. Identification of a Problematic Situation

When a group of scholars communicate with each other in a ListServer context of communication, many things are accomplished with words, on-line: calls for conferences, papers, jobs and applicants are posted; research findings are shared and discussed; bibliographies are compiled; exciting discussions occur, focused on book and article reviews, concepts and issues of concern; activists pass along political information in net-based activism. With members geographically dispersed and most face to face strangers, how does a group of scholars establish itself as an on-line community? What are the characteristics of language (forms and functions) used to mediate the creation, nurturance and sense of community on-line? And, in turn, so what? Why is it important that such communities exist? These questions have guided this analysis of the flow of on-line communication.

3. Overview of the Study

During three years I logged on to ten, subsequently five electronic mailing lists referred to as the x-lists. The lists, based in Southern California, were used by an international, 400 member group of academic scholars who shared a declared concern for "issues in education in modern technological societies and a special concern about ways in which educational systems are a source of socially engendered inequalities". Communication was supported by a ListServer program which enabled subscribers to post messages to a list in such a way that all subscribers to the list received copies of the posts. Members also communicated with each other privately in side-channeled communication and small groups.

The on-line flow of communication generated by this community, and as it appeared on my computer screen in the form of posted e-mail messages, was the focus of this study.

4. Procedures

Three kinds of data were collected using a standard ethnographic method of participant observation: computer messages, responses to interviews and a small survey I posted on-line. Altogether, and to date, about 150, 400k diskettes of e-mail messages have been collected. Interviews (25) and survey responses (30) were collected face to face, by telephone and on-line. Interview and survey procedures entered into an early (first year) cycle of analytical induction functioning as an initial incursion into the community. It turned out, however, that old-timer interviewees supplied me with invaluable insights; and significantly, that several survey respondents were from the silent (lurking) majority supplying me with an illuminating picture of this activity. In turn, this prompted me to post a small analysis of survey results on-line. Finally, as I worked my way into the community, I found more natural ways to build my experience and understanding: in personal communication; in the Permission for Citation Process; and in the occurring on-line conversations[1].

5. Analyses

To make sense of the flow of on-line communication I combined notions from Soviet Activity theory (Engeström, 1988; Leonte'v, 1981; Wertsch, 1981) and a Conversation for Action discursive model of communication (Murray, 1991; Winograd and Flores, 1986). From Soviet Activity theory I borrowed the notions of activity system and the metaphor of the water molecule (Vygotsky in Moll, 1990) whose elements, hydrogen and oxygen, are seen as functionally irreducible to the whole (i.e.; hydrogen and oxygen separately function as combustors). Using these two notions I determined that viewed in its totality, the flow of on-line communication occurring on my computer screen was an activity system in its own right. This activity system, I called electronic academia. Looking for tasks and actions within that system I then differentiated tasks such as logging on and off invoked by tool usage from action realized in messaging such as requesting bibliographic information.

From Conversation for Action I borrowed two notions: the notion that speech acts cohere into recursive patterns of communication called conversations; and the notion that conversations travel across modes and media of communication. These two notions enabled me to look for relationship among messages and the utterances embodied within them both of which are constitutive, though irreducible to the activity system of electronic academia. Three such recurrent patterns of communication were identified: academic, administrative and community-building. Findings pertaining to community-building action are reported here.

6. Findings

6.1. Naming the community

The origins of the x-lists with its double meaning prefix "x" was perhaps a first order indicator of the desire to build and sustain community. Created in 1984, the lists had been set up to maintain communication among a small group of scholars (the "ex-scholars) who, for economic and other reasons, were dispersed and no longer working together at the research laboratory of the host site. Founded in this spirit list mem-

[1]Voluntary consent was unsollicited as communication occurring on line was considered public. I announced my research intent on-line, however, in the posted survey; and conformed to the x-list protocol of sollicting citation permission for messages and making available all of the work that I wrote in connection with the x-lists, including survey responses stripped of headers to preserve anonymity.

bership had grown to the present 400 member community.

The name of the community and its double functioning prefix was picked creatively by list members who addressed each other in terms that played on this name and it dual significance. For example, members addressed each other in the following terms: "Hello X-class-ers.."; "Dear X-acting colleagues..."; "Dear ... and other X-Lister's"; "Hello X-classers"; "Dear exacters"; "Dear X-classiests"; "Dear Friends of the XFAMILY"; "Dear Xmain-ites"; "Dear Xcompers and Xclassers"; "Hello xpracticers"; "Hey ho out there in xpractice-land".

In this way the community was named and this name was re-formulated and appropriated creatively, to build community, in the acceptance and nurturance of this identity.

6.2. Civil language use

The language in use on the x-lists was warm and playful; grateful and positive. Expression of playfulness and warmth existed in friendly forms of address marking relations of solidarity in contrast to those of power (Brown and Gilman, 1960). Members addressed each other, signed off and referenced each other's work mostly on a first name basis. In sign-offs for example, the sequence -preferred name/ first+last name was often used, including short comments expressing such feelings as hesitation, congeniality, timidity and modesty, all of which may be seen as converging to mark dimensions of relational equality to build community. The following are examples of sign-offs

- mike as in MC
- Math is fun -Mary Ann
- *Sigh*, who said modern life was easy? :-(Edouard
- joe -Joszef A. Txx
- Existentially yours... Edouard
- I will stop myself here. Phew! :-) C.T.
- Nic -Nic Sxx
- Puzzled -Arne
- Robert (a perplexed and marginal participant in
- Russ -Russell A. Hxx
- Sigh- Margaret American society)
- Bertram (Chip) Bxx
- *Heavy sigh* :-(Edouard
- L*
- My two cents worth. Ilda C. Kxx

Civility also existed in a positive attitude with expressions of gratefulness and appreciation, including praise. The following are a few examples of this civility:

- Bravo Meghan...
- E-U-R-E-K-A! Now that observation is as perfect example of the nature of RE-mediation as anyone could hope
- This is a wonderful statement
- Gordon, thank you for the thoughtful and informed consideration of major themes in the 3 articles in Educational Researcher
- The recent postings by W. have been a great help for me in evaluating what sort of direction to follow working with elementary aged students. Thank you, everyone of you.
- Deborah, that was a fantastic summary of the Griffin and Cole article.
- To all of us. Thank us all for provoking interesting discussions. I don't regret spending a couple of hours reading and responding to messages during the week-end.

A civility marked by such spirit as sheer admiration, enthusiasm, support and appreciation for on-line activity.

7. Functions: Growth and Continuity

Community building action may be seen as functionally different from academic and administrative action, constitutive of the flow of on-line communication. Community-building conversations are intended to grow rather to exhaust or close themselves. This means that they function in a different time frame compared to the discrete and punctual frames of academic and administrative action. Community-building conversations are in essence continuous. They are geared towards creating cohesive ties in and of the group. Their locus is exclusive to the on-line space, even if they may be re-inforced by off-line ties and in turn lend themselves to the creation of off-line ties. Finally, it is in these conversations that intangibles are negotiated. Action is at the feeling and spiritiual levels: with feelings such as warmth, acceptance, validation, belonging and trust negotiated; and spirituality in the form of respect, tolerance and gratitude actively transacted.

8. Discussion: Why Community?

To explore the forms and functions of language use through which community is created and nurtured circumscribes the existence of community as phenomenon. This precludes the deeper issue of why such communities exist. Community-building conversations provide perhaps in essence what the psychological literature calls "ersatz": a compensation of sorts after the severance of both primary bonds (parents) and secondary bonds (teachers): a peer solidarity in the solitude of journeys. As one community member posted " I'm raising all of this at length on X-list because it is precisely here that I have found a great deal of companionship in my heresy -- and damn little elsewhere". Far from the publish and perish drive of academic and administrative action, these conversations are nonetheless vital to productivity and conceptual change. For the degree to which they are successful in enabling communication is a vital condition of productivity, and in this particular case for the making and diffusion of knowledge. This is to say that where community is truly successful, the flow of on-line communication is both source and outlet for activity. In turn, the principle of community can be used to inform the design of telecommunications technology in different domains of professional activity (e.g.; for teachers as in the LabNet project -DiMauro and Jacobs, 1995).

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Technology Support for Collaborative Learning in a Problem-Based Curriculum for Sustainable Technology

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Abstract

Sustainable technology has been defined as technology that provides for our current needs without sacrificing the ability of future populations to sustain themselves. Designing sustainably engineered solutions requires weighing the qualities of different proposals from a variety of different perspectives and handling a variety of tradeoffs simultaneously. Of necessity, these problems must be solved in multidisciplinary groups. Students, therefore, need to learn not only what their own disciplines have to say about the issues, but they also need to be able to recognize other issues that arise and to know which disciplines can contribute to their solutions. Thus, students need to learn how to recognize new issues and to work collaboratively.

One possible solution is for students to learn by working on cases in multidisciplinary teams These multidisciplinary groups provide opportunities for collaboration and reflection that have the potential to greatly enhance student learning. Technology plays an important role in supporting such collaboration and reflection. In particular, this curriculum makes use of the Collaborative and Multimedia Interactive Learning Environment (CaMILE) to scaffold collaboration and reflection.

Keywords — case-based methods of instruction, tools to support teaching in collaborative settings, instructional strategies and approaches.

1. Introduction

"Sustainable Development" is an ill-defined concept. In fact, part of the educational challenge is the ambiguity and imprecision of the term. As our point of departure, we take it to mean "meeting the needs of today without compromising the ability of future generations to grow and prosper" [1]. As we head into the 21st century, this concept of sustainable development will become increasingly important.

The curriculum in sustainable development and technology cuts across all engineering disciplines, within a multidisciplinary environment incorporating the latest advances in cognitive science and computer-supported learning. This curriculum introduces major changes in the way engineering students learn within a problem–based collaborative learning environment. To make a difference, engineers need to become better informed about the world in which we live, and the social, economic and environmental problems we face in the future. They need to formally incorporate environmental planning at all stages of project development.

The new curriculum is intended to develop and strengthen students' integrative skills in analysis, synthesis, and contextual understanding of problems. Part of the initiative in sustainable technology includes support for the design, development and assessment of teaching and learning tools. A specific tool being used for this curriculum is CaMILE (Collaborative and Multimedia Interactive Learning Environment) an en vironment for sharing electronic media (e.g., video, spreadsheets, world wide web resources) and structuring discussion. The educational approach being adopted consists of starting with a three course sequence, and then migrating the ideas and concepts from these courses into the general curriculum. The first course is intended to expose the students to a framework in which questions about sustainability can be posed. This framework is based on four dimensions of sustainability: technology, economics, ecology, and ethics (Stan Carpenter, personal communication 1994). The second course in the sequence will employ this background to focus on a series of case studies using a problem-based-learning (PBL) approach [2]. The third course will involve more open-ended problem solving by an interdisciplinary team of students.

The content, educational goals, and methods of the second course, are the focus of this paper. The structure of the paper is as follows: An overview of problem-based learning is presented which is followed by a discussion of technology support for collaboration and reflection. We then discuss the curriculum in sustainable technology and the problems that have been developed. Finally, we present the lessons that we have learned regarding the use of the collaboration environment and the future directions for our work.

1.1. Problem-based Learning

Problem-based learning is a student-centered, contextualized approach to schooling. In this approach, learning begins with a problem to be solved rather than content to be mastered. This is consistent with new models of teaching and learning that suggest the emphasis of instruction needs to shift from teaching as knowledge transmission to less teacher-dependent learning. Learning needs to occur in problem-oriented situations if it is to be available for later use in those contexts [3]. PBL was originally developed to help medical students learn the basic biomedical sciences [2]. PBL includes among its goals: (1) developing scientific understanding through real-world cases (2) developing reasoning strategies, and (3) developing self-directed learning strategies. Since its origin in medical education, PBL has been used in other settings such as engineering and architecture [4].

As students articulate and reflect upon their knowledge in PBL, they develop more coherent understandings of the problem space [5]. In addition, the acquisition and indexing of examples that occurs during PBL should allow later problems to be solved by case-based reasoning [6]. Finally, the active learning used in PBL should promote the self-directed learning strategies and attitudes needed for lifelong learning [7]. The self-directed learning objectives of PBL are particularly important in science and engineering because PBL may facilitate development of the lifelong learning strategies necessary to stay current in the face of rapid technological advances. The use of PBL requires collaboration. Unlike the model used in the medical schools, the Georgia Tech students are taking this course along with several other traditional courses. This makes collaboration outside class difficult. Moreover, in the limited amount of time in class, the students do not have sufficient time to reflect. For these two reasons, we felt that a computer-supported collaborative learning environment would help make our PBL course more effective. The next section of the paper will discuss the technological tool we are using to support the students' collaboration, reflection, and learning.

1.2 Technology for collaboration and reflection

Collaborative learning is a key part of the PBL approach. As students articulate and reflect upon their knowledge, learning and transfer are facilitated [8]. Group problem-solving allows students to tackle more complex problems than they could on their own. Students do not necessarily collaborate well nor do they necessarily take opportunities for reflection [9]. The techniques that teachers use to support students engaging in an activity and learning skills are called scaffolding [10]. The goal of scaffolding is (1) to enable students to carry out a reasoning process or achieve a goal that they would not be able to do without help and (2) to facilitate learning to achieve the goal without support. As students learn the skill, they need less support, so the scaffolding can be faded. Research on software-realized scaffolding shows that some of the help traditionally given by individual coaches can be provided through software [10].

The major tool we use to support collaboration is CaMILE, an interactive, distributed, collaboration environment that scaffolds learning, reflection, access to materials, and problem-solving tools [11] This environment supports collaboration through the NoteBase in which students enter comments of various types. Students reflect on their thinking as they choose the type of note they enter. The students can attach documents of various forms to the their notes and can create links to the MediaBase, a multimedia repository of additional information, and to resources on the World Wide Web.

CaMILE provides software-realized scaffolding by the use of procedural facilitation. Procedural facilitation in CaMILE encourages students to think about the role their contribution is making to the problem-solving process itself. Students use this environment as a tool at times when they need to collaborate to complete a project and when it is integral to an assignment. When students click on the attached documents the document and its application is opened allowing students to work collaboratively on shared documents. By encouraging reflection as students collaborate, the students are more likely to construct usable knowledge and to transfer what they have learned to other problem-solving situations. [8]

2. Overview of Curriculum and Pedagogy

Using our experience in chemical engineering, mechanical design, and problem-based learning, three case studies in sustainable development have been developed (Table 1). Each case includes a factual case text, supplementary material that provides case enrichment, and a guide for the facilitators. Students are expected to expand the study of cases beyond these materials by identifying issues and exploring resources on their own. The role of the class instructor is (1) to facilitate discussion around issues of technology, environment, economics, and ethics and (2) to encourage the use of fundamental principles and tools to address these issues.

Table 1. Case Studies and Issues in Sustainable Development.

CASE:	ISSUES:
1. Learning from Industrial Accidents - Bhopal.	Accidental chemical releases; chemical toxicity.
2. Sheet Molding Compound Manufacture.	Impact assessment and reduction; sustainability and economical trade-offs in industry.
3. The sustainability of Chlorine use - A Pulp and Paper Mill.	Overall approach to chemical use.

A goal of each case is to expose students to a broader perspective of real-world problems while having them draw upon their disciplinary knowledge to collaboratively develop solutions. Three cases have been developed for use in the problem-based second course. A common theme in these cases is that they involve the production and use of chemicals and their fate and transport in the environment. Application of principles of mass and material balancing, dynamic and steady state response, and life-cycle assessment is required in each case to assess issues of technology, economy, environment, and ethics. Cases 1 and 2 focus on particular sites. Case 3 is broad, addressing issues at the global, national, or industrial level. In all cases, emphasis is given to the recovery and reuse of product, raw material, and/or energy. Topics addressed include the technical feasibility and economic tradeoffs of alternative processes and products; preservation and efficient use of material, energy, and space; and uncertainty in data in material properties, global, regional and local inventories, and health risk information.

This course is being taught as a 3 credit problem-based elective. There are a cross-section of students from a variety of engineering disciplines enrolled in the class. To introduce students to the concept of sustainable development and sustainability dimensions, three cases were selected for study: Learning from Industrial Accidents- Bhopal, Premix' Sheet Molding Compound Manufacture, and Chlorine Use in a Pulp and Paper Mill. Throughout the course, students were encouraged to use CaMILE to assist them in their collaborative efforts by encouraging them to post their questions and to engage in dialogue around these questions and their collective problem-solving efforts.

3. Assessment Issues

In examining the success of this program, we considered the students' learning from both group and individual perspectives. Group assessment examined collaboration and consideration of sustainability issues. This was accomplished by analysis of the groups' activities, student logs, and case reports. In addition, the students' collaborative discourse via CaMILE was considered. We assessed individual learning and transfer of both the content they have learned and the values of sustainable technology to new problems by written pre- and post- testing of the students' knowledge of sustainable technology. Finally, we assessed the students' understanding of the nature of the issues in sustainable development by having them develop and present cases that can be used for future reference. This provided an opportunity for students to make their thinking visible and provided a way to assess thinking that was also a learning opportunity for students.

The first time this course was offered was in the spring quarter of 1995. We had some successes and some disappointments. In general, the students learned about the issues of sustainable technology [12]. The students became better at examining the ethical, environmental, and economic issues of sustainability. They did not however learn to apply their technical knowledge. One reason for this may have been that the students construed the technical issues narrowly and thus failed to reflect upon how broadly applicable their technical knowledge was. Another explanation is that the students divided up the issues such that one person in each group handled the technical issues and did not successfully communicate that back to the working groups.

4. Lessons Learned

The first time through the course, our use of CaMILE was not very successful. The students did not collaborate very well nor did they appear to reflect on broader issues. Some of the students noted in their logs that they were not sure they understand what sustainability meant. CaMILE would have been an excellent forum for reflection on these issues. Several attempts to start discussions were made by the course faculty and an occasional student but discussions never got longer than 2 notes.

There were a variety of explanations for the lack of success. This may have been caused by (1) access problems, (2) hardware platform incompatibilities, (3) failure to adequately integrate the collaboration technology into the course.

The version of CaMILE that we were using only ran on a Macintosh. This caused two types of problems. First, students needed to use the public computer clusters to access CaMILE. This was inconvenient for many students. In addition, students wanted to be able to access CaMILE from their dormitories which was not possible with the Macintosh version of CaMILE. Another barrier to use was that many of the students used PC-compatible hardware platforms and did not want to learn to use a Macintosh. These students also had to deal with software incompatibilities because the PC versions of some of the software were higher than the Mac versions that were available in the clusters.

Finally, the lack of explicit integration of CaMILE into the course was probably the major reason for our lack of success in using CaMILE. Students were encouraged rather than required to use CaMILE but the benefits to the students were not made clear. In the students' logs, they noted how difficult it was to collaborate and to meet outside class. They also noted that it was hard for them to do more than attach their documents together the day that a paper or case study was due. The reports that the students handed in were consistent with the lack of integration. Despite the collaboration difficulties, the students had no idea how CaMILE might be of benefit.

5. Future Directions

Our pilot implementation of this course has provided data that will inform subsequent instructional practice. Based on further analysis of our experience, we are working on developing better ways of integrating CaMILE into the course. Some barriers will be overcome by the new version of CaMILE which runs on the World Wide Web. Understanding the nature of collaboration and the role of technology in supporting collaborative problem-based learning is an ongoing issue in our work. Computer-supported collaborative learning environments have the potential to enhance PBL in exciting ways, but to realize that potential will require consideration of how they should be integrated into the classroom environment.

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Collaborative Information Networks

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Abstract

In a proposed Collaborative Information Network (CIN) individuals could monitor and index a limited number of information sources and share the results with others in the network thus increasing their efficiency. Background research into developing a model for implementing Collaborative Information Networks is presented. A Collaborative Information Network on the topic of International Careers and Employment is used to describe current research and development. After that Future Networks, and Collaborative Research are discussed. To illustrate collaborative research an example of how a Collaborative Information Network could be developed by participants at CSCL95 is given.

Keywords — Collaborative Information Networks, Educational Networks, Cooperative Searching.

1. Introduction

It is proposed that the collaborative monitoring, indexing and disseminating of information is more efficient than the current practise of individual monitoring. Individuals in a collaborative network would monitor and index a limited number of information sources and share the results with others in the network. This would allow the collective monitoring of more sources of information, than possible by individual monitoring.

The indexing of information according to its usefulness to other users in the network would save time monitoring information of little or no use. The common index developed would eliminate the need for a variety of systems to obtain an overview of information from a variety of sources and/or in different formats. The index would be especially useful for viewing short clips of multimedia and audio-visual material before reviewing the entire package. Further development of the index could provide a comprehensive system for direct access to information from a variety of sources.

In a collaborative system (such as Internet) information sharing patterns, tools and systems, are user and standard dominated. In centralized systems (such as Compuserve) information sharing patterns, tools and systems are economically and system dominated. It is proposed that collaborative network tools and information networks can be developed, which will compete and surpass the effectiveness of centralized systems. "Without tools and methodologies for gathering, evaluating, managing, and presenting information, the Web's potential as a universe of knowledge could be lost. ... A flood of information unfiltered by the critical and noise-reducing influences of collaboration and peer review can overwhelm users and obscure the value of the Web itself." [1].

In summary, individuals participating in a collaborative network should be able to improve both the quantity and quality of the information they monitor. Users in a collaborative network will have more influence on information sharing patterns, tools and systems than in centrally controlled networks. In this paper developing Collaborative Information Networks is discussed in relationship to past, present and future developments.

2. Developing Collaborative Information Networks

The author is currently developing a Collaborative Information Network (CIN) on the topic of "International Careers and Employment". Background to this network is discussed first, then Laying a Network Foundation for the network and last building on this foundation..

2.1. Background

The author has had an interest in cooperative (collaborative) information systems since the early 1970s. In the late 80s he did research in China which resulted in "A Model for Implementing Cooperative Information Systems in Chinese Academic Institutions" [2]. Although several factors were considered in developing the model, the emphasis was on cultural and social factors [3].

Further research and collaboration resulted in "A Model for Implementing a Cooperative Multimedia Information Network"... This model assumes four stages to the innovation process: Needs Analysis, Initiation, Implementation and Outcomes" [4]. The above is presented as background to a discussion on current efforts to develop a Collaborative Information Network.

2.2. Laying a Foundation

The author proposes to use existing technology and information, to begin a CIN (Collaborative Information Network) at the university of Alberta. Then once the network is established it will be opened up to the Internet community. Initial searches of the university library and Internet, indicate that the best general Canadian source of information on International Careers and Employment is a newly released second edition of a book. This book has good indexes to selected bibliographies and organizations. These indexes, bibliographies, and organizational lists could serve as foundation indexes and lists for new information. All bibliographic information in the book is recommended, most items have been reviewed and some items are designated as "editor's choice". This recommendation and review process can be used as a model for future additions to the network. Excerpts from the book are already available through the International Center's W3 (World-Wide Web) home page. One concern in putting the book on line is intellectual property rights. This concern needs to be carefully considered by W3 [5] and CIN developers.

Another source of foundational information is existing information on Internet. An initial search found several job services, one of which was international in scope and has been linked to the W3 pages of the International Center at the University.

In addition to an information foundation, a CIN needs a people foundation. To lay this foundation, the author is recruiting people interested in the topic to be CIN editors. This can involve three types of activities: creating new information, adding new information and updating existing information. It is hoped that these activities will provide a "collaborative filtering" [6] of information according to its usefulness to other users. The International Center at the university has already put their information on Internet and others are considering doing this. It is anticipated that each W3 page will have an editor responsible for the content. Once this foundation of editors and an information structure is in place the network can be opened up to others and new information added.

2.3. Building on The Foundation

As people use a CIN, they can also contribute to its development. Additional information can be added and the location (i.e. local library call numbers) of information items identified. This would be done by sending email messages to an editor. Other items of information may have already been identified. One such item is an "International Career Quotient" test. This test provides a good overview of ones preparedness for an international career. It could also be used as an index to information especially for items on which one scored low. Another source of information is a local organization which has over 400 audio-visual materials. Initially the catalog to these materials could be made available on Internet. As time and funding permits short review clips from recommended items and full versions of selected items could be added. Another way of finding additional information is the collaborative analysis of cooperative searches [7].

Another source of information is user comments and information from newsgroups. An initial search of "job" newsgroups, did not find any newsgroups dedicated to international employment. Separate sections of the bibliographic index could be used for comments from users and newsgroups. There may also be an advantage to have these comments divided into temporary and permanent categories.

Another way of expanding the network would be to develop "instructional networks" for students studying subjects related to international careers and employment. In an instructional network information could be indexed according to topics listed in the course outline. Each student could be assigned to edit a specific topic. Students could conduct searches, which could be added to the network through student editors. Teachers (Professors, Instructors) could then edit the students work for the next class of students. They could also pass the information on to an appropriate editor from the broader International Career and Employment CIN. As CINs standards and interfaces are developed, it is anticipated that much of the information sharing process would be automated in future networks.

3. Future Networks

What has been described so far in this paper, is the potential for developing CINs using today's technology and information. A brief outline of potential structures, standards, interfaces, and research needed to develop widely used CINs is presented below.

3.1. Structures and Standards

The simple people networks of students, teachers and local editors need to be expanded into national and international networks. This could be done by developing local, national and international coordinating committees. In addition committees need to be set up to handle issues like copyright and network ethics. Central processing facilities need to be set up so that users can locate CINs which are appropriate to their information needs.

Standards for information exchange could be an extension of HTML (Hypertext Markup Language) and other standards for W3 (World-Wide Web). One standard needed is for bibliographic information. Another is for contact information (name, organization, phone, fax etc.). Standard review clips for audio-visual and multimedia materials could be used to save network resources. Other standards could be built into interface tools.

3.2. Interface Tools

Basic interface tools based on existing W3 (Internet) tools like Netscape and Mosaic could be developed for using, linking and editing CIN documents. Some of the W3 tools being developed may be useful in developing CINs. For example, tools are being developed for collaborative authoring [8] guided tours [9] "Navigational View" Building [10] Virtual Classrooms [11] and "A distributed software development environment supporting cooperative work" [12]. In addition to the current features of programs like Netscape, the basic user interface would need features for processing bibliographic and contact information. The interface should also be compatible with other programs so that information stored in CIN format could be used in Word Processors, Fax Programs, databases etc.. Interface tools should provide for personal indexing, storing, and tagging of information.

Users could subscribe to CINs at various levels. Some of the levels which could be specified are: geographical location, recommendation (by editors and other users), content (introductory, advanced, general or specific. CIN users should also be able to order full version of items which are not available online or for which their is a charge. In order, to provide anonymous feedback usage statistics (i.e. did the user print, read, and/or store the information), could be gathered and forwarded to editors. Comments and other information could also be sent to the editor.

The basic editors' interface would have all the features of the basic user interface plus features for editing. Items could be easily added to existing information (point and click on menus). Recommendations could be made either by the editor or from usage statistics and user comments. Advanced editing functions would be done using an advanced editing interface (for editorial committees). Some of these functions would be to approve new groups and editors, to change indexes, to set standards and network practices.

3.3. Collaborative Research

To develop future CINs considerable research is needed. To date most of the research has be conducted by the author. At this stage he is looking for others to collaborate in the research. One way to facilitate collaboration would be to develop a CIN on collaborative networks. Coordinating and standards committees could be set up and editors and users recruited on the basis of their research interest. Another way to further CIN research would be to set up a network on CSCL (Computer Supported Collaborative Learning). CSCL '95 conference proceedings could act as a information foundation. People networks could be set up by using conference "Topics of Interest" to recruit editors and users.

4. Conclusion

In order for CINs to work the collaborative efforts of many people are needed. With tighter budgets and time constraints, will we find the time to work collaboratively? Or will centralized systems dominate the next century so that only the rich have access to the bulk of the world's information. Whether CINs as outlined in this paper or some other system(s) dominate information access in the next century, it is hoped that the relatively free access to information enjoyed by the public (especially the academic community) can be maintained.

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Playing Together Beats Playing Apart, Especially for Girls

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Abstract

This paper describes studies focusing on how gender and grouping affects performance and attitudes of children playing a puzzle solving game called *The Incredible Machine*. We found that children playing together on one machine solved significantly more puzzles than children playing alone on one machine. Female/Female pairs playing together on one machine, on average, completed significantly more puzzles than Female/Female pairs playing side-by-side on two computers. In addition, the level of motivation to continue playing the game was affected by the opportunity to play with a partner, and success in the game.

Keywords — Human-Computer Interaction, Computer-Supported Collaborative Learning, Computer-Supported Cooperative Work, Children, Education, Gender, Games.

1. Introduction

Children naturally tend to gather in groups around computers and video games. This is common in arcades, living rooms, and classrooms, but was also overwhelmingly evident during a research study of children playing electronic games conducted at an interactive science museum, Science World, in 1993. This paper describes follow-on studies focusing on how gender and grouping affects performance and attitudes of children playing a puzzle solving game.

The Science World 1993 study was the first research undertaken by the Electronic Games for Education in Math and Science (E-GEMS) group, an ongoing collaborative effort among scientists, mathematicians, educators, professional game developers, classroom teachers, and children. The goal of E-GEMS is to motivate children to learn and explore mathematical and scientific concepts through the use of electronic games. E-GEMS research includes focused studies on specific issues [7], long term qualitative investigations [9], development and evaluation of prototypes, and design of commercial products [2].

Science World is an interactive science museum where children and adults explore scientific concepts through a variety of hands-on activities. In July 1993 E-GEMS researchers set up an exhibit at Science World to observe children as they interacted with video games and computer games. During the two month exhibit, over ten thousand children spent time in the exhibit and several hundred children were interviewed by researchers. Two strong themes that emerged from our observations were the popularity of collaborative play and differences in gender preferences and playing styles. Gender differences are reported in detail elsewhere [6,10]. This paper presents the outcomes of a two-phase further investigation of collaborative play conducted in a school classroom in January 1994 and at Science World in the summer of 1994.

Researchers have noted positive benefits from small group interactions around computers in the classroom [4,11,15]. Some studies include comparisons between individual, cooperative, and competitive groupings [8,3]. In our study we chose to focus on the playing configuration rather than explicitly forcing children into competitive or collaborative playing modes. Children were placed in one of three physical set-ups:

Solo Play:	one child alone on one machine
Parallel Play:	two children side-by-side on two machines
Integrated Play:	two children together on a single machine

The game chosen, *The Incredible Machine* (TIM), is a problem solving game in which players assemble Rube Goldberg style machines out of a collection of parts to solve challenges posed by the game. Typical challenges include building a machine to shoot a basketball into a hoop and trapping Mort the Mouse in his cage. The parts include many used in everyday life (e.g. gears, pulleys, ropes, ramps and levers) along with a host of characters and entertaining objects (e.g. cats, mice, balloons, various types of balls, and trampolines). During the Science World 1993 study, researchers frequently observed collaboration on TIM by groups of children, including groups of children who had never previously met.

At Science World 1993, many groups of children played TIM for extended periods of time. Some groups passed control of the mouse back and forth while other groups had one person perform the group's suggestions. Often, the children in the group were active participants in sharing ideas and directing actions within the game. The children who played TIM in groups appeared to play for longer periods of time and appeared better able to solve the puzzles. These observations led us to hypothesize that children playing TIM in pairs would, on average, complete more puzzles during a fixed period of time, and would choose to play longer.

2. TIM Study

2.1. Phase I: Kerrisdale School, 1994

The first phase of the current TIM study was conducted at Kerrisdale Elementary School, a public elementary school in an upper-middle class neighborhood of Vancouver, British Columbia, Canada. The participants were 104 children (52 girls and 52 boys) between the ages of 9 and 12 who had not previously played TIM. Students were arbitrarily placed into one of the three experimental conditions described above, namely Solo Play, Parallel Play and Integrated Play. For the two-player conditions, the students were randomly assigned a partner corresponding to a particular sex-dyad. The gender groupings were: Female/Female, Male/Male, and Female/Male.

The setting was an empty classroom equipped with either one or two IBM-compatible computers, depending on the experimental condition. The total length of each session was forty minutes. The children were welcomed and given a brief introduction to the project and the environment. Next, the children were asked to try to complete the first three puzzles in the game and told that they were allowed to play for as long as they desired up to a maximum of thirty minutes. The children were given no directions on how to play to game. The game manual was placed on the table beside the computer and the children were told that it contained information about the game and that they could look at it if they wished. They were encouraged to try to work out any problems they might have amongst themselves. The children were also told that when they finished playing, they could come into another section of the room for a snack. Once in the snack room, the children completed a questionnaire and engaged in casual discussion until their forty minutes was completed. Following this, they returned to their classes.

The factors investigated in this study were achievement in the game (the total number of puzzles completed by each student), and motivation to play the game (whether or not the children played the game for the full thirty minute period allowed). Qualitative observations were also gathered concerning the cooperative play of the children and the group dynamics for the Parallel Play and Integrated Play conditions.

Table 1 shows the mean number of puzzles completed during each of the experimental conditions. Both girls and boys solved more puzzles in the Integrated Play condition than in the Solo Play condition, although the difference was not significant due to the small sample size.

The result for the Parallel Play condition was dependent on gender. Girls solved, on average, fewer puzzles in the Parallel Play condition than in the Solo condition. In addition, girls in the Integrated Play condition solved significantly more puzzles than girls in the Parallel Play condition, with $p<.05$.

These results indicate that children's success when playing with a partner may depend on the children's playing configuration and gender groupings. We did not observe any effect on motivation since only five children left before the thirty minute session was over.

2.2. Phase II: Science World, 1994

Because of the intriguing differences observed in Phase I for achievement by girls in the Parallel Play and Integrated Play conditions, we decided to repeat the study

Table 1. Kerrisdale Elementary School Mean Number of Puzzles Completed

		Solo	Integrated Same-Sex Pairing	Integrated Mixed-Sex Pairing	Parallel Same-Sex Pairing	Parallel Mixed-Sex Pairing
	Mean	1.88	2.20	2.14	0.42	1.00
Female	SD	1.54	1.83	2.23	0.76	2.00
	n	8	20	7	12	5
	Mean	1.75	2.40	2.14	2.50	1.80
Male	SD	2.05	2.00	2.23	1.55	1.94
	n	8	20	7	12	5

with a larger sample size at Science World during the summer of 1994.

This phase of the research project used 331 children (247 girls and 84 boys) between the ages of 9 and 13; the disproportionate number of girls was deliberate because of the wide variation in results for girls observed during the first phase. The children who participated were visitors to Science World who volunteered to take part in the study. As before, none of the subjects had previously played the computer game TIM. Students were randomly chosen to play either alone or with a partner in one of the three experimental conditions. This time partners were chosen corresponding to one of two sex dyads: Female/Female or Male/Male. No mixed gender pairs were used.

The Research Lab at Science World contained four Macintosh LCIII computers set up so that four sessions could run simultaneously. The procedure for running each session was identical to that in Phase I, except that no snacks or questionnaires were involved. When the children finished playing, they left the exhibit and continued exploring Science World. The factors measured for this study were the same as in Phase I, namely achievement and motivation.

Table 2. Science World BC Mean Number of Puzzles Completed

		Solo	Parallel	Integrated
	Mean	1.21	0.98	1.83
Female	SD	1.85	1.45	1.65
	n	155	46	46
	Mean	2.35	2.78	3.3
Male	SD	2.7	2.02	2.43
	n	46	18	20

The average number of puzzles solved in each of the experimental conditions in Phase II are shown in Table 2. In Phase II, gender (female and male) and experimental condition (Solo Play, Parallel Play, and Integrated Play) had a statistically significant effect on the number of puzzles solved in the game, with $p<.001$ and $p<.03$ respectively.

The results from this study validate the trend observed in Phase I that girls and boys solved more puzzles playing together on one machine in the Integrated Play condition than playing by themselves in the Solo Play condition, with $p<.05$. In addition, the discrepancies observed in the Parallel Play condition were also repeated, i.e. girls solved statistically fewer puzzles in the Parallel Play condition than girls playing in the Integrated Play condition, with $p<.06$. Also, as observed in Phase I, girls in the Parallel Play condition solved on average fewer puzzles than girls in the Solo Play condition. On the other hand, boys solved more puzzles on average in the Parallel Play condition than in the Solo Play condition but fewer puzzles than in the Integrated Play condition although these differences was not statistically significant.

These results support previous reports in [1,3,13] demonstrating the advantages of small groups sharing a single computer. This seems especially true for girls, given that girls playing together on one machine solved significantly more puzzles than girls playing side-by-side on two machine.

The increased number of puzzles solved in the Integrated conditions for both girls and boys could be attributed to the necessary interaction that occurs while working together on one machine. This resulted in more verbal interaction in the Integrated Play condition than in the Parallel Play condition. This observation of increased verbal interaction during collaborative work on one machine is supported by another study [13] in which children playing together on one machine had more verbal interactions than children playing side-by-side on two machines. Elaboration, the discussion of and expanding on ideas, is recognized by many researchers as one of the underlying cognitive explanations of the benefits of cooperative learning [12].

Gender differences in achievement were significant in Phase II in contrast to Phase I. Girls solved significantly fewer puzzles in all conditions than boys, with $p < .001$. This result could be explained by many factors including differences in the environment, the selection process, and the type of platform and interaction style used. Phase I took place in an empty room in a school, during school hours. Phase II was in a science museum with many people wandering around the exhibit throughout the session. In addition, Phase II took place during summer break, leading to differences in the selection process. In Phase I almost all the children in eligible classes chose to participate since it was viewed as a desirable break from their regular school day. At Science World the children who took part gave up time that they could have spent at other highly attractive exhibits. The interface used in TIM also differed slightly between the phases because of the use of different computer platforms. The IBM-compatible implementation of TIM uses a point-and-click style of interface whereas the Macintosh implementation in Phase II uses a drag-and-drop style. A subsequent study of girls using both these interfaces showed a slight difference in the average number of puzzles solved [5]. In this study girls using the point-and-click interface on the IBM-compatible computer solved more puzzles than girls using the drag-and-drop interface on the Macintosh computer.

Phase II also demonstrated that playing configuration has a significant effect on motivation as measured by the number of children who stayed and played for the full thirty minute session. The percentages of children who left early are shown in Table 3. A higher percentage of children left during the Solo Play condition than for the Parallel and Integrated Play condition. In addition, fewer girls left during the Integrated Play condition than in the Parallel Play condition. This result might be explained by two factors: success in the game and whether or not the child played with a partner. Success in the game seemed critical since of the 54 children who left early, all but three left before solving any puzzles. The presence of a partner may also have contributed to staying for the full thirty minute session, since a similar percentage of girls in the Solo Play and Parallel Play conditions could not solve any puzzles, 58% and 58.7% respectively, but a higher percentage of girls in the Solo Play condition left early.

Table 3. Percentage of Children who Left the Session Early

	Solo Play	Parallel Play	Integrated Play
Girls	21.3%	17.4%	4.3%
Boys	15.2%	11.0%	10.0%

3. Conclusions and Future Work

This study provides a basis for several directions of future research. Although much has been done in the area of computer-supported cooperative learning, further examination of the effect of technology is needed.

Previous literature of cooperative learning on computer tasks emphasizes how the teacher can structure cooperative tasks and group compositions to maximize academic and social benefits using existing technology. It is important to investigate whether some of the benefits of cooperative learning may be enhanced by changes in the computer hardware, the software, or the choice of user interfaces. Especially intriguing is the opportunity to adapt Computer-Supported Cooperative Work (CSCW) inspired multi-person interfaces to educational software. There is also a need for further research in multi-input systems and other shared-screen issues.

Although students in this study enjoyed to work with friends, they sometimes had difficulty sharing the input device. In a later study, the addition of a second mouse to TIM was shown to have a positive effect on achievement for children collaborating on one machine [7]. A system that allows children to work together as well as maintaining the ability for individual exploration may be an important advance in cooperative learning with computers.

The results of this study suggest that grouping children around one computer can positively affect performance as compared to children playing alone on one machine. In the case of Female/Female groupings, working together on one machine can have a significant benefit over working side-by-side on two machines. These results, combined with the extensively researched social benefits of cooperative learning, demonstrate a need to continue research and development in this direction.

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Operationalizing Mental Models: Strategies for Assessing Mental Models to Support Meaningful Learning and Design-Supportive Learning Environments

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Abstract

Mental models are the conceptual and operational representations that humans develop while interacting with complex systems. Being able to reliably and validly operationalize users' mental models will help us to assess advanced knowledge and problem solving skills acquired while interacting with constructivist learning environments. Additionally, understanding effective and ineffective models will provide us advice for designing the kinds of scaffolding, modeling, and coaching that should be included in learning environments to support effective mental model deveelpment. This paper describes an initial study assessing the mental models of novice and experienced refrigeration technicians.

Keywords — mental models, advanced knowledge acquisition, problem solving and transfer, designing constructivist learning environments.

1. Introduction

Most constructivist learning environments, including cognitive flexibility hypertexts (Spiro & Jeng, 1990), anchored instruction (Cogniton & Technology Group, 1992), goal-based scenarios (Schank (1993/1994), causally modeled diagnostic cases (Jonassen, Mann, & Ambruso,in press), share a common goal: the construction of advanced knowledge by learners that will support complex performance, such as problem solving and transfer of learning. These environments stress situated problem solving tasks, because those are the nature of tasks that are called on and rewarded in the real world. In most professions, people are paid to solve problems, not to memorize information.

While advanced knowledge, higher order thinking, problem solving, and transfer of learning evoke common associations and expectations in most of us, there remains an operational inexactitude in these constructs. Just how do we know when leaners have constructed advanced knowledge? How advanced or higher order does that knowledge have to be? How do we assess it? In this paper, I argue that these learning outcomes can best be operationalized and predicted by assessing and understanding learners' mental models of the problem or content domain being learned. Why? Because solving situated, ill-structured problems in different settings requires the solver to use complex and diverse mental representations. Problem solving performance can be at least partially explained by the quality of the mental models of the problem solvers (Gott, Benett, & Gillet, 1988).

The purpose of this paper is to begin to explore the utility of mental models as learning outcomes from using complex and situated learning environments. In order to provide useful recommendations, it is necessary to formulate clear and operationalizable representations of mental models and then to assess changes in those models that may result from complex interactions with constructivist learning environments. If that is possible, then it will be potentially useful to reverse engineer appropriate types of structures in those environments to support the various kinds of mental model development that can be expected from those environments. This paper seeks to develop and asses an operational definition of mental models which can be used to assess advanced knowledge acquisition and transferable learning.

2. Mental Models

The construct, mental models, emerged from the human computer interaction field as a mental metaphor for describing the conceptions that humans develop for internally describing the location, function, and structure of objects and phenomena in computer systems. The facility with which users apply and exploit the functionality of computer systems depends, mental model theorists argue, on their conceptual models for describing the components and interactions of those systems. Are mental models merely conceptual? Mental models have been distinguished from other types of models that are also used to aid the development of user interfaces (Farooq & Dominick, 1988):

- **Cognitive Models.** Cognitive models are typically developed by cognitive psychologists, using information processing conceptions of skills and propositions, to describe the processes that humans use to perform some tasks such as solving problems, using a computer system, programming computers, etc. Among the most prominent cognitive models is the GOMS Model (Card, Moran, & Newell, 1983) that conceives of system-using activities in terms of Goals, Operators, Methods, and Selection rules (GOMS). Such models are task-specific and are often used to design interfaces and intelligent tutoring systems. They describe the goals, operators (processing activities), and methods needed to accomplish the goal state in terms of expert performance. Cognitive models, unlike conceptual or mental models, are not concerned with how users or learners actually conceive of tasks or systems.

- **Conceptual Models.** System designers often construct conceptual models of a system to show the users how they should conceive of the system. Mayer (1989) reviewed several of his own studies on the provision of conceptual models in learning BASIC, the camera, database systems, physics, and other content domains. He concluded that providing concrete, conceptual models for learners improves conceptual retention, reduces verbatim recall, and improves problem solving transfer. Showing learners how ideas are interconnected in the form of concrete models enhances the learners' mental models of the content being studied.

- **Mental Models.** Mental models are the conceptions of a system that develop in the mind of the user. Mental models possess representations of objects or events in systems and the structural relationships between those objects and events. Mental models evolve inductively as the user interacts with the system, often resulting in analogical, incomplete, or even fragmentary representations of how the system works (Farooq & Dominick, 1988). Unlike cognitive and conceptual models that describe how users should represent a domain or system, mental models describe how users or learners actually conceive of the system or domain. Moran (1981) expresses the belief of many designers that the design of the system controls the mental model that is developed by the user, so an ideal user's mental model would be congruent with the conceptual model of the interface as developed by the designers. However, Moray (1987) makes the argument that mental models evolve instead as homomorphs of the system's structure rather than isomorphs. Users' mental models usually vary, often significantly, from the cognitive or conceptual model promoted by the designers because of varying prior knowledge, individual abilities, and different beliefs about the purpose and functions of the system.

Although some claim that the term mental models relates only to conceptions of computer systems that users evolve, we agree with many psychologists that the concept is generalizable to most content domains and processes as well as general world knowledge. Mental models, according to Norman (1983), are the internal representations that humans develop of themselves and the objects they interact with in the world. Johnson-Laird (1983) believes that "human beings understand the world by constructing models of it in their minds." Building mental models is an important component in accommodating to the world, and to use a Piagetian construct, equilibrating differences between what is "in the world" and what is understood by the knower. That belief is institutionalized in the learning taxonomy developed by Kyllonen and Shute (1989), which contends that rote, didactic, deductive, and inductive learning methods result in the development of propositions and skills which form the basis for mental models. The construction of mental models "requires the concerted exercise of multiple skills applied to elaborate schemata" (p. 132). Like all taxonomies of learning, propositions are prerequisite to the acquisitions of related schemas and skills, which in turn are prerequisite to mental models.

3. Operationalizing Mental Models

Mental models are theoretical constructs, so we do not know where and how they develop? A common theory for describing mental model development is analogical or metaphorical reasoning (Staggers & Norcio, 1993). That is, learners generalize existing models to new phenomena through a process known as structure-mapping, that is, mapping the old structural relations onto new (Gentner & Gentner, 1983). For example, flowing water helps most people develop a mental model for electricity. Most theories believe that mental models consist of objects and their relationships (Gentner & Gentner, 1983; Carley & Palmquist, 1992). The objects are concepts or nodes, and the relationships are links or verbs that state the nature of the relationships between objects. The node-link combinations are combined into networks or maps of relationships that describe the domain of knowledge represented by a mental model. All of these conceptions of mental models are based on a set of assumptions stated by Carley and Palmquist (1992):

(1) Mental models are internal representations.

(2) Language is the key to understanding mental models; i.e.. they are linguistically mediated.

(3) Mental models can be represented as networks of concepts.

(4) The meanings for the concepts are embedded in their relationships to other concepts.

(5) The social meaning of concepts is derived from the intersection of different individuals' mental models.

These assumptions, we believe, are probably necessary but not sufficient for defining mental models.

3.1. Components of Mental Models

Generally, mental models are thought to consist of an awareness of the structural components of the system and their descriptions and functions, knowledge of the structural interrelatedness of those components, a causal model describing and predicting the performance of the system (often formalized by production rules), and a runnable model of how the system functions (Gott, Benett, & Gillet, 1988; deKleer & Brown, 1988).

Mental models have been assessed using a variety of methods, including think-alouds and verbal protocols, online protocols (audit trails), problem solving and troubleshooting performance, information retention over time, observations of system use, users' explanations of systems, and users' predictions about system preformance (Sasse, 1991). These data are often collected while users interact with experimental versions of systems, causing Sasse to conclude that such findigs are often flawed because the experimental scenarios are too restrictive and artificial, an insufficient range of information is collected, and samples are too small and too often reflect only novice users.

Mental models are more than structural maps of components. They are dynamic constructions. They are multimodal as well as multi-dimensional. Mental models are complex and inherently epistemic, that is, they form the basis for expressing how we know what we know. Because mental models are epistemic, they are not readily known to others and, in fact, not necessarily comprehended by the knower. Mental models, like all knowledge, must be inferred from performance of some sort.

3.2. Method

In this initial study, we will be studying the mental models of refrigeration technicians. We have selected a group of six novices (students in the final semester of a two-year, technical college program in refrigeration technology, and at least three experts (refrigeration technicians who have worked for six or more years for a major supermarket chain). All of the participants are male, between 20 and 38 years of age. For each paticipant, we will present him with the description of a complex refrigeration problem. In the contextof that problem, we will collect the following kinds of data:

- **Structural knowledge.** Structural knowledge is the knowledge of the structure of concepts in a knowledge domain and can be measured in a variety of ways (Jonassen et al, 1993). A number of researchers have used structural knowledge methods to develop representations of mental models. For example, Pathfinder nets generated from relatedness data were generated to depict mental model (Kraiger & Salas, 1993). Carley and Palmquist (1992) use their own software for constructing interlinked concept circles (maps) based upon text analysis or interviews. These methods all rest on the assumptions that cognitive structure can modeled using symbols (Carley & Palmquist, 1992) and that semantic proximity can be represented in terms of geometric space (Jonassen et al, 1993). Using structural knowledge methods to model mental models further assumes that they can be represented as networks. In this study, we will use Pathfinder nets to analyze the structural knowledgeusig a constrained setof 20 refrigeration systems concepts. While we believe that networks of interconnected knowledge underlay mental models, they cannot function adequately as the sole means of representation.

- **Performance/Procedual Knowledge** It is essential that learners be required to perform problem solving tasks. Kyllonen and Shute (1989) recommend process outcome predictions for assessing mental models, that is, performing some task, such as troubleshooting a simulated task or "walking through" a performance test. "Running" the model has received limited investigation of simple concepts to qualitatively test the visual images in their heads (diSessa, 1983). These will be assessed using think-aloud protocol analysis while solving the problem provided. In addition to providing performance problems that need to be solved, learners should be required to articulate their plan for solving the problem, and they should be observed on how well they adhere to the plan, what stratgies they use for dealing with discrepant data and events, and finally what kinds of generalizable conclusion they can draw from the solution. These data can probaby best be gathered by having learners think aloud while solving the problem. We propose to intervene and prompt the learner at various stages with questions requiring them to explain or infer why certain results occurred and to make predictions about what will happen next.

- **Reflective procedural knowledge.** An increasingly common method for assessing mental models is the teach-back procedure, in which learners or users are asked to teach another learner (typically a novice) how to perform certain tasks or how to use a system. Students often produce a variety of representations, such as a list of commands, verbal descriptions of task components, flow charts of semantic components, descriptions of keystrokes (van der Veer, 1989).

- **Image of system.** Wittgenstein (1922) described propositions as imaginal models of reality. Most humans generate mental images of verbal representations. The statement, "The stone gained speed as it rolled down the steep slope" is meaningful only when an image of a mountain with a stone descending along its side is generated. Mental models definitely include mental images of the application of domain knowledge. So, it is important to elicit the learner's mental image of a prototype of the system s/he is constructing. Some learning environents accommodate this need by providing an "envisioning machine" that displays system objects in different views (Roschelle, 1987). However, such envisioning tools map representations or views of the world that may not be consonant with the learners'. So, in this study,we require learners to articulate and visualize their "runnable" physical models or the physical devices or processes (Gott et al, 1986) using interviews

- **Metaphors.** In addition to imaginal representations, humans naturally tend to relate new systems to exisiting knowledge, often by associating them with other physical objects. A recent interview with an engineer produced a "marshmallow" metaphor for molecules. While most metaphors are not as distinctive, they are important means for uunderstanding peoples' mental models. We will therefore require the participants to generate metaphors or analogies of the system involved in the performance,asking them to explain the similarities between the efrigeration system and the metaphor.

- **Executive knowledge.** It is not enough to have a runnable model of a domain or process, but in order to solve ill-structured problems it is essential to know when to run which model. Knowing when to activate mental models allows the learner to allocate and apply necessary cognitive resources to various applications. This can only be assessed by presenting a variety of problems to solve. That is not possible in this initial study.

These data are currently being collected, and exerpts of these interviews will be used to illustrate this model in the conference presentation. The mental models of the participants will be evaluated using the following criteria.

3.3. Criteria for Evaluating Mental Models

Since mental models are process-oriented and relatively intangible, and since they need to be assessed using multiple data sources, an important goal of this research is to identify potentially useful criteria for assessing the quality and utility of individual mental models. A rational analysis of the construct suggests the following criteria:

CHARACTERISTIC	MEASURE
Coherence	Structural knowledge, Think-aloud
Purpose/ Personal Relevance	Self-report, Cognitive interview
Integration	Cognitive simulation
Fidelity with Real World	Comparison to expert
Imagery	Generating metaphors, analogies
Complexity	Structural knowledge
Applicability/ Transferability	Teach back, think aloud
Inferential/ Implicational Ability	Running the model

4. Implications of Mental Models for Design Practice

We expect that these interviews will show that situated experience will be positively related to richer, more structurally coherent, and efficient mental models. We are currently negotiating contracts to design and develop case-based learning environments to support the refrigeration technology curriculum. The findings from this study, comparing the mental models of experts and novices, should provide directly relevant information about the nature of the scaffolding, modeling, and coaching that needs to be embedded in these environments, as well as providing us with measurement devices for assessing the advanced knowledge that we hope they will help learners to construct.

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Towards a Pedagogy of Informatics

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Abstract

Developing a Pedagogy of Informatics[1] involves collaboration in learning at a number of levels, i.e. the collaboration of educators as they work together on the conceptual and operational changes required if they are to teach both *about* the computer and *with* the computer; the collaboration of students as they learn together through activity-based and challenging learning opportunities; the collaboration of schools and communities as they come to terms with the role of education and schooling in the *information* society; and interdisciplinary collaboration in the development of curricula and educational programs.

In this paper we discuss the challenges facing educators to incorporate informatics into the curriculum, and review a new educational program in Northeast Brazil. We will outline the *capacitation*[2] of teachers that occurred, and present a package of teaching and student materials which formed the basis of a course in informatics for K-12 students. These materials which were developed in Portuguese are currently being translated into English at the University of Oregon.

Keywords — informatics education, educative informatics.

[1] We have used the term *Informatics* (Information + automatics), because it places computer education in the broader context of information and technology.

[2] Neologism for continuing professional development which enables and empowers teachers to action.

1. Introduction

In recent years many Brazilian institutions have studied informatics and its application in education, science and technology, and gained more experience in its use. Despite differences in methodology and context most of these studies focused on the fundamental need to manage the technology and to explore its resources in order to improve the educative, productive and scientific process of knowledge generation in the Brazilian society. Computers were introduced into educational programs for children with the "promise" or "belief" that through the computer students would learn more, read better, and work more creatively and cooperatively. However, the computer, reified in this way, has not corresponded to people's expectations of its potential in the learning and teaching situation.

A closer look at computer usage in schools shows that the main focus of computer education in schools has been on *computer skills*, e.g. word processing or information management, and little attention has been given to developing a pedagogy which integrates the teaching of computer skills with an understanding of informatics and its place in our society. Little or no attention has been given to what we have called a *Pedagogy of Informatics* which takes into consideration the learning and teaching processes, the organization of curriculum, and reflection on people/machine relationships in learning and in the wider community, as well as developing children's ability to use computers competently. Recent research in the US, Japan, Israel and some countries in the European community also shows this lack of focus on the *Pedagogy of Informatics* (Pelgrum & Plumb, 1991; Anderson, 1993; Lund & Wild, 1993; VISION TEST, 1990; Office of Technology Assessment, 1995).

The challenge facing educators today is not just to *use* computers at school, but to use computer education and informatics to mediate improved social and learning relations in schools. The introduction of informatics into the curriculum can assist schools to change from a traditional way of teaching and learning, to one that provides students with an ever more cooperative apprenticeship in the learning and teaching process, and prepares them to be lifelong learners, explorers and integrators of learning and experience. A key factor is assisting schools to respond to these challenges is the production of resource materials suitable for use with students at all stages of the educational process. However to be effective, these materials must express didactically the basic educational concepts that will facilitate the processes of working, teaching, communicating, and learning (or even '*literacing*', in a society such as Brazil's as it moves towards its informatization). (Costa Lima & Jurema, 1993)

2. A Project and Experience

A computer education program produced by ITECI, a Brazilian enterprise, and based on this emerging pedagogy of informatics, has contributed to our knowledge about the use of computers and information technology in education. These materials were trialed through an intensive course, and then successfully used for more than two years in eight Elementary and Middle Schools, with approximately 4,000 children and adolescents in the cities of Recife and Natal. With some adaptations the course was also taught to a group of children with special needs (Jurema, Jurema & Longman, 1992). Our observations are based on the conceptual framework on which the program was based, the multidisciplinary and collaborative approach to the program development and implementation, and the follow-up evaluation of ITECI's methodology and courses.

The program integrated two key objectives:

- ***Informatics education***: to provide students with access to systemic knowledge about computers and information technology;

- ***Educative informatics***: to use computers and information technology as an educational resource for students and schools.

Both students and teachers need to master the machine, but if these skills alone form the basis of the program, there is a risk that students and teachers will behave like parrots (mere repeaters) without understanding what they are doing. On the other hand students who conceptually understand the structure and functioning of computers and software in both historic and contemporary contexts, will be able to infer, take risks and face new challenges creatively. This program therefore aimed to provide students (and teachers) with both the practical formation necessary for familiar and fluent use of computers and software, and the comprehension of how computers work and the part they play in our society.

ITECI took a multidisciplinary and cooperative approach to the development of the program by establishing a working team of professionals in the areas of informatics, cognitive psychology, education, visual programming (graphics), history, and a specialist in the production of didactic materials.

3. Foundations for developing a program based on the Pedagogy of Informatics

The multi-disicplinary team based the development of the program on a number of *foundational* premises, i.e.

- The interdisciplinary nature of informatics knowledge involves a range of subject areas and processes, including but not limited to mathematical, historical, linguistic, logical, conceptual, and graphic.

- Learners are active participants who in the course of their learning structure their experience and knowledge (Piaget).

- The cooperative work of students and teachers creates a new cultural resource which is greater than the knowledge and understanding that any of the individuals possessed before (Vygotsky) (Veer & Valsiner, 1991).

- Approaches which are based on the social and cognitive reality of students will develop learning experiences that are challenging and open-ended, enjoyable and playful, cooperative and socializing.

- Computers are a *means* not an *end*. In the educative process they do not replace people but assist them in reorganizing interactions, thus reorganizing the teaching and learning process (and the play).

- The content of knowledge and its daily application are intrinsically related. Therefore teaching and learning programs in addition to providing information about computers and information technology, must be functionally constructed (authentic learning), and also challenge learners to reflect on social impacts and implications (i.e. the relations of people with the machine and with one another).

- Informatics in schools are not an appendix to the educative process, but an integrated element of the school curriculum which must enrich the teaching and learning situation.

- The *capacitation* of teachers is essential. An approach based on the pedagogy of informatics requires teachers to develop their own knowledge and understanding of informatics in our society, to rethink their roles and practices, and base their teaching on their students' curiosity and active involvement in their learning.

4. The program

The working team produced an *Introductory Informatics Course for Children and Adolescents* (Jurema & Costa Lima, 1993) which included both a methodology for teaching informatics to children and adolescents (K-12), and a series of teaching and learning programs across the age-range. It was designed to assist children and adolescents develop the abilities, understandings and values necessary to participate effectively in a society impregnated by computers and information technology. The K-12 focus also required that the multi-disciplinary aspect of school life be considered and promoted, and that informatics education be developed as an integrative element across the curriculum. The course was designed around three thematic nuclei:

- Foundations of Informatics (history, functioning and uses of the computer)
- Informatics and Society (social impact and vocational and work market analysis)
- Interest centers (workshops on many topics, including but not limited to, art, games, literature, mathematics, literature, pedagogical support, library)

The program materials include a kit of didactic materials: text books (reference books for students and teachers), activity challenges for students, manuals of methodological orientation and educational programs for teachers, and a support kit of educational software.

The software developed are simple, requiring the teacher to explore the ideas they represent and integrate them into the learning program. The teachers' manual presents, besides suggestions for activities, some alternative suggestions about ways to work with students within each subject, and the integration of the program across the curriculum.

Collaborative processes are built into all activities of the program so that the cooperative and cognitive elements are intrinsically united, e.g. when children work in teams to create databases, they generate findings which have to be discussed, analyzed and communicated, and require their active involvement in the reasoning process.

5. The role of the teacher

As they began the project, the working team knew that motivating teachers to find time to learn a different methodology and approach, was certainly one of the biggest challenge they would face. The *capacitation* of teachers is the key to the success of the program. If informatics is to become and intrinsic component of schooling, it will not be enough for schools systems to merely "train computer experts". All teachers must be given the opportunity and the encouragement to the develop the conceptual understanding and technical skill necessary to integrate the computer into their educational programs. Each teacher must also explore and *navigate* in the space provided by the activities and the software, in order to learn themselves, and to facilitate students' learning. In addition, as teachers face new challenges together, the *cooperative apprenticeship* in technology, represented by the computer can play a considerable role, offering teachers the opportunity for collaborative work across disciplines, as well as within particular disciplines.

The teacher capacitation program developed by the project aimed to assist teachers to become users and teachers of informatics, through understanding the philosophy, ideas and skills on which ITECI had based the program. It is an ongoing process, including a practical course of micro-informatics (*40 hours*), monthly teacher meetings (*3 hours*), and end of semester workshops (*6 hours*). At each monthly meeting the teachers discuss basic concepts of informatics, and ways of using informatics in schools, (both within disciplines and across disciplines). Every meeting is based on specific aspects or experiences brought up by the teachers themselves. The workshops include presentations by experts in specific areas (*3 hours*) and hands-on experience for participants (*3 hours*).

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A Cooperative System for Collaborative Problem Solving

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Abstract

In the DSA-project (Dialogue Structure Analysis of interactive problem solving) we are studying the relationship between the cognitive aspects of information processing and the communicative process of information exchange during cooperative problem solving. On the basis of analyses of dialogues of students collaborating on a problem solving task, a prototype of an 'intelligent' computer-based cooperative system has been implemented.

This program, the 'Dialogue Monitor', is the central part of a computer-assisted educational program, which acts as a simulated student and which collaborates with a human student in jointly solving this problem task. In this paper we will focus on crucial aspects of cooperative interaction in problem-solving learning situations, which we found hard to implement in our system. These aspects concern the complex interaction between task strategies and communication processes during collaboration. Real collaboration requires that the cooperating subjects acquire a common frame of reference in order to negotiate and communicate their individual viewpoints and inferences.

Keywords — cooperative learning, intelligent tutoring systems, human-computer interaction.

1. Introduction

Contemporary views on learning and technology stress the importance of collaborative learning. Computer and telematics based environments seem especially suited for such learning.

Research on cooperative learning in education has a long-standing tradition. In recent educational research cooperative learning is re-emphasized [2]. This emphasis follows a reformulation of learning as a process of enculturation in recent constructivistic or situated learning views on cognition and instruction [3, 5] Aspects of cooperation play a central role in the constructivistic approach of learning. Peer cooperation is seen in a Vygotskian way as an intermediate stage in the developmental process of internalization of social activities. Furthermore notions like cognitive apprenticeship, anchored instruction and scaffolding partly seem to be based on a cooperative paradigm.

As for the role computers play with regard to education, the focus is on the construction of computer-based, multimedia environments: open learning environments which may give rise to multiple authentic learning experiences [3]. The cooperative aspect is mainly realized by offering computerized (intelligent) tools which can be helpful for collaborating students in solving the task at hand. Cooperative systems aimed at working together in one way or another with a student or a group of students, is another approach. In this approach a computer-based 'intelligent' partner or a simulated peer student is used to facilitate the effects of cooperative learning [4, 7, 10]. In order to implement a cooperative system as a partner in this sense, the emphasis will have to be on the requirements for communication and interaction between the collaborating partners, i.e. the system and the student(s).

However, we lack specific knowledge about the way students communicate and thereby coordinate their information processing while collaborating in problem solving contexts. When students cooperate and communicate in natural language, information is exchanged, not only concerning the problem itself but also about meta-cognitive aspects such as the plausibility of the information and beliefs about the state of the information of the other [8].

2. Cooperative Problem Solving

At the Utrecht University, the DSA-project ("Dialogue Structure Analysis of interactive problem solving") is concerned with research on the relation between information processing and information exchange during cooperative problem solving. In this project a simulation-program has been constructed that models a cooperative peer student on a problem-solving task.

2.1. Cooperation task

The task that is used to study the relation between information exchange and information processing during cooperative problem solving is called the "Camp Puzzle". It is meant for students from the highest grades of elementary school (10-12 years old). The Camp Puzzle may be compared to the so-called "Smith, Jones and Robinson" problems. In this kind of logical problems one has to combine different statements of information in order to derive some characteristics of a specified group of individuals. However, in the Camp Puzzle this task information has been split (in two 'letters' of children in this group) and has been distributed among the two cooperating partners. By this splitting of information cooperation becomes necessary in order to complete the task. The students have to infer several characteristics of the six children mentioned in the task. Each of the two partners receives a letter which contains different information about the children mentioned in the task.

2.2. Cooperation dialogues

In two research projects the Camp Puzzle was assigned to couples of students in the highest grade of elementary school (72 and 20 couples). Their task-dialogues were collected on video or audio tapes. By means of a comprehensive system the utterances in the dialogues could be coded along three main characteristics: content (in the form of a proposition), dialogue-act and illocution. The dialogue-act represents the communicative action of an utterance, for example: question, proposal, denial, statement, etc. The illocution part of an utterance provides the listener explicit information on how to interpret the information transferred. In most cases the illocution concerns the certainty of the information, for instance "I am not sure that..".

From analyses of the cooperative task-dialogues, it was learned that mutual coordination and communication of relevant information and inferences during cooperative problem solving is a complex intertwined and dynamically changing process. The topical structure in the argumentative dialogues coincide with the subproblem structure of the task. However, the sequence of sub-problems is not rigid and a solution path has to be found. For this purpose, topics have to be initiated, tried and evaluated in the ongoing dialogue. Remarkably, topics are seldom explicitly proposed, but are initiated implicitly by exchanging relevant information concerning a topic.

Most of the dialogue-acts in the Camp Puzzle are informative, supportive or argumentative. Contrary to what one would expect, the dialogues contain very few open questions (e.g. "Do you know the sports of Jan ?"). The students seem to hold on to another Cooperative Principle (compare Grice, [6]): "If my partner has found something interesting, he will tell me, I don't have to ask for it !". Yes/No questions are found more frequently (e.g. "Does Jan play volleyball?"). These latter type of questions function, mostly, to check information exchanged. Furthermore, the students are very concerned with the plausibility or certainty of the propositions transferred or inferred by themselves or by their partners (25% of the utterances have an explicit illocution part). Several plausibility levels (five in our model) can be distinguished, depending on the source of information and on the depth and complexity of the inference procedure.

2.3. Dialogue Monitor

Based on analysis of the dialogue protocols a prototype of a Dialogue Monitor for a cooperative system was developed, simulating a cooperative student. The 'Dialogue Monitor' program has been experimentally used with 51 students (10-12 years) of two elementary schools. The architecture model advanced in this program will be used for further development of 'intelligent' computer-based cooperative systems. In the model of the Dialogue Monitor five components, functioning as separate modules, may be distinguished.

The 'Problem Solving Component' contains knowledge about the content of the task and its domain and is able to apply inference procedures in order to solve this type of problems. The 'Dialogue Processor' contains expertise about interaction processes in general and has strategies for generating communicative actions: i.e. argumentative, supporting and eliciting scenario's. In the 'Alter Component' a discourse history is been updated in the ongoing dialogue. Based on this history a belief-system about the current activities of the partner is construed.

The 'Central Focusing Processor' contains the cooperation strategies. The general task of the Central Focusing Processor is to interpret and check incoming utterances of the partner and to generate utterances itself in a reacting or initiating way. The communication with the program takes place with the 'Menu-Based 'natural language' Interface'. By means of interconnected menu's the student can select constituents of the utterance he/she wants to make [9]. The selections made by the student are translated into a grammatically correct sentence. With the interface a large amount of different sentences can be made (about 3.2 million).

3. Implementation of Interactivity

3.1. Coordinating

When we look at sequences of communicative actions that occur frequently between human students, we can distinguish some prevailing dialogue-patterns. Every phase in the problem solving process has its congruent part in the topical structure of the task-dialogue:

- *Problem definition - Proposing*
  Initiating and agreeing about the next topic of discourse, i.e. the next sub-problem to be tackled.

- *Information search - Informing*
  Searching for relevant information in information sources, including communicating and eliciting information from the partner.

- *Inferencing - Argumenting*
  Getting a joint understanding about the way of combining the relevant information.

- *Evaluation - Concluding*
  Evaluating and agreeing upon a possible solution.

- *Finishing - Topic closure*
  Writing down a solution or giving up.

Coordination occurs by means of signaling, asking for attention before new information is transferred, and by means of explicitly accepting and re-concluding before writing down the solution. By these means, both partners explicitly make sure that they share the same understanding of the problem. However, a lot of coordination is achieved by implicit means. With respect to the implementation in the Dialogue Monitor, we tried to solve this by the interpretation of a verbal act on two levels: locally (the dialogue-act) and in regard to the topical structure (topic-step). In general however, a cooperative system should deal with this multiplicity of functions of discourse acts in the situated context of the ongoing dialogue.

3.2. Mixed initiative

Both system and student have to be able to take the initiative in interaction. They must be able to take initiative in asking questions, in making remarks, in transferring information, in suggesting solutions. However, questions for implementation concern the "when" and "what then" of taking initiative. When should the system take the initiative? And how should the program react on an initiative of the partner? Being concerned about taking initiative in the interaction is not a trivial matter, as most user-system interaction systems wait for a reaction of the user ('press enter or OK-button'). As a rule a cooperative system should take the initiative if it can contribute some interesting or helpful information.

A fragment of a dialogue between the Dialogue Monitor and a student is given in Figure 1, which illustrates this aspect of mixed-initiative and flexibility in change of focus. A fragment, literally translated from Dutch, is shown of the interaction of the monitor with a 12-year old student.

Dialogue fragment (translated from Dutch)	
1	*M: "Let's search: the city of Peter."*
2	*M: "Children living in Haarlem, sleep next to each other; that is in my letter."*
3	*A: "And Peter comes from Sittard; that is in my letter."*
4	*M: "Oh,..."*
5	*M: "We can write that : Peter comes from Sittard."*
6	*M: "I'll write that !"* [*i.e. fills the solution in the solution-matrix*]
7	*A: "Peter does the same sports as Mary; I am sure of that."*
8	*M: "Oh..."*
9	*M: "The sport of Peter; that is not in my letter."*
10	*A: "And only one child is playing volleyball, that is in my letter."*
11	*M: "Only one child is playing volleyball."*
12	*M: "I don't know that."*
13	*M: "Is only one child playing volleyball ?"*
14	*A: "Yes; that is correct."*
16	*M: "So, only one child is playing volleyball"*
17	*A: "Ann comes from Assen."*
18	*M: "Yes, Ann comes from Assen, that fits."*
20	*M: "That is in the solution-matrix."*

Figure 1. Dialogue between a 12 year-old male student (A:) and the Dialogue Monitor (M:).

As can be seen in the fragment, the dialogue has a "natural" stance with a lot of implicit proposals, ellipsis ("Yes", "Oh"), non-specific replies, plausibility checking (13) and unexpected topic-shifts (7, 17) of the partner. In the first topic (the city of Peter) the monitor takes the initiative (1) and the student follows. The second topic on the same subject (sports of Peter) is initiated by the student (7) and accepted by the monitor. When this topic fails, the student initiates a sub-problem (17), which already has been solved

3.3. Checking

One of the main findings of our analyses of the protocols, is that students spend a great deal of their time in these task-oriented dialogues on coordinating activities such as checking of plausibility and giving information about the status of information transferred .

Checking procedures were found to play an important role in the coordination of actions in the analyzed task-dialogues. We think that before information can be incorporated in a cognitive representation, this checking process on relevance and coherence with earlier knowledge is necessary. People can only relate external information to their own knowledge if it is perceived as relevant, plausible and consistent [1]. The importance of "checking" the information put forward by the partner is reflected by a checking procedure by the central focusing processor of the Dialogue Monitor, which operates on every incoming utterance.

3.4. Negotiating

If cooperation also means the negotiation of knowledge, this implies that under specified conditions the cooperative system will have to 'buy' the argumentation of its partner, even if it counters its own conclusions. We think this is a difficult problem to solve as it concerns belief revision. In contra-argumentation, disagreeing with the line of reasoning of the partner, one of the cooperation partners should be convinced in the end. The problem is to specify the conditions under which the program will have to loose its faith in its own line of reasoning. We are not satisfied with the rigid, standardized way the program acts in situations of contra-argumentation at this moment. Contra-argumentation will be accepted if the plausibility of the own information is minimal or if the partner persists in changing earlier found conclusions. More research on natural argumentation and persuasion will be needed in order to specify the negotiating of knowledge by a cooperative system

4. Conclusion

In this paper we focused on some aspects of cooperation, which in our view are crucial, but hard to implement in computer-based cooperative systems. Real collaboration requires that the cooperating subjects acquire a common frame of reference in order to be able to negotiate and communicate their individual viewpoints. Natural language communication is implicit by nature, viewpoints are not always advanced, task strategies are not always open to discussion, and so forth. While implicitness may be ineffective because it masks differences in knowledge, viewpoints and attitudes, it also results in efficient and non-redundant transfer of information. Coordination in information transfer is accomplished by multifunctional dialogue acts. With respect to the implementation of computer-based cooperative systems, this puts a heavy burden on the interpretative and generative power of the program. Most notably, it should deal with the functions of discourse acts in the situated context when interpreting verbal acts of its human partner and it should use those same functions when generating its own verbal acts.

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Using a Game for Social Setting in a Learning Environment: *AlgoArena* — A Tool for Learning Software Design

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Abstract

AlgoArena is a tool for education of software design to beginners. The purpose is to develop the ability to think algorithmically and the ability to view things systematically. It is a simulation game of sumo wrestling — the traditional Japanese national sport. Students are supposed to program the actions of their own wrestler using a programming language so as to win matches against other wrestlers. To make the wrestler stronger, students are encouraged to analyze the chaotic situation systematically, devise better tactics, and incorporate them into the program. Such comprehensive problem-solving activities are comparable to the processes involved in software design. In addition, students commit to solving their own problems at their own responsibility. It is also comparable to the authentic activities of a software designer. In this sense, activities with AlgoArena can be regarded as a significant 'epitome' of authentic software design.

Social setting for the learning environment is attributable to constraints embedded in the system of AlgoArena. For example, owing to the constraint of the game that a player needs opponents to fight with, students are encouraged to have matches with others, and social interaction among students is facilitated. In this way, a game situation is brought into the context of learning and produces a community of learners.

Keywords — simulation game, collaborative learning, situated learning, computer literacy, programming language, software education, Logo.

1. Introduction

According to a theory of situated cognition, learning is regarded as a process of enculturation [1], and it occurs as newcomers gradually increase their participation in a community of practice [3]. Learning is thus inseparable from practice. From this viewpoint, Brown pointed out one problem of schooling as follows:

> *Most classroom activity inevitably takes place within the culture of schooling, but it is attributed by both teachers and students to the cultures of readers, writers, mathematicians, historians, and so on. What students do in school thus tends to be a sort of ersatz activity, distorting both what is learned and the culture to which it is attributed [1].*

The most rigid interpretation of this claim would demand 'on the job training (OJT)', i.e., an educational method in which students take part in actual practice at the workplace, such as in conventional apprenticeships. In reality, however, it is not always possible for students to become members of the actual community as apprentices only for the learning experience. First, from the viewpoint of the workplace, the community's capacity to accept excessive numbers of apprentices is inadequate by ordinary. The community of practice is not able to afford to educate students who are not expected to become regular member. Second, from the viewpoint of students, they will have less opportunity to experience various cultures, because OJT is generally a very time-consuming process, whereas they should be enabled to encounter a wide variety of cultures. For these reasons, it would be impracticable to educate everyone on the basis of OJT.

As a result, the authors have left the framework of conventional schooling as it is, and have tried to bring realistic culture of practice into culture of schooling. Although practice at school cannot be the same as it is at the workplace, we believe that it is possible to inject student's activities with 'reality' of actual practice. Before getting into the details of our approach, let us clarify what we mean by 'reality'.

The authors think that actual experiences have at least two aspects. One aspect of reality is perceptual reality. It concerns the similarity between perceptions caused by physical stimuli in the real world. Virtual reality accomplishes reality in this sense. For example, when a student works with the same tools that established members use for authentic activities, perceptual reality for the activity is high in the sense that he/she can feel, touch, hear, smell, and see the same things as the members do.

On the other hand, there is another aspect to actual experience, namely, social reality. It concerns the similarity between the social commitments created by acts. Every act inevitably produces some social commitment to others. For example, articulating "This is a pen." is not only a description of the state of affairs, but produces a speaker's commitment to a listener regarding the existence of the pen. That is why the speaker is anticipated to disprove, if someone says, "It is a pencil." or "I cannot find a pen." Out of the network of such commitments, meanings for acts emerge. Therefore, it can also be stated that social reality concerns the similarity between meanings of acts.

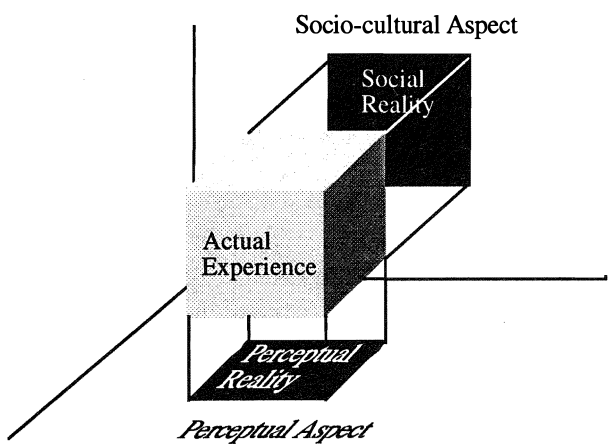

Figure 1. Relationship between social reality and perceptual reality.

Both aspects of reality are, connected by actual experience, orthogonal as shown in Figure 1. That is, there can be situations that have high perceptual reality and low social reality at the same time, or vice versa.

Suppose that you are participating in a role-play dialog with a native speaker to learn a foreign language. You can listen to the fluent pronunciation of the native speaker, look at his/her gestures, and even shake hands. What you perceive there is much the same as what those who speak the dialog as a part of their authentic activities perceive, so it has a high perceptual reality. However, such a speech-act does not produce a similar commitment such as an authentic speech does. For example, articulating "Let's meet there then." in real life usually commits a speaker to the listener such that the speaker must go to the designated place at the designated time. However, if the words are spoken in the role-play dialog, the speaker is not expected to do so. This is why the act in the role-play has low social reality.

However, when you are communicating via a computer terminal using a chat program (a real-time communication system with characters and alphanumerics on screen), such as 'talk' in UNIX, you are unable to listen to live voices, or look at the speaker's facial expressions. Instead, you are forced to read strings of featureless characters. Therefore, the act has relatively low perceptual reality, compared to ordinary conversation. However, sending a string of "Let's meet there then." produces the sender's commitment to a receiver for carrying out the appointment, which is as valid as the appointment by face-to-face talk. Hence, the act has high social reality.

Regarding education, perceptual reality can be supported by various media in a learning environment. In particular, multimedia technology, such as full color images and high fidelity sounds, can contribute primarily to this aspect of reality. Meanwhile, social reality is affected by the social settings of a learning environment. Specifically, it depends on the means of organizing student activities, putting them into context, and maintaining the community of students.

As Brown pointed out in the earlier quotation, activities at school tend to be a somewhat ersatz. This is partly because the environment in which activities take place is quite different from the workplace, i.e., lack of perceptual reality. Another reason that should be taken into account is the lack of social reality. That is, students at school tend to commit to their teacher for learning activities, while established members of the community of practice commit for the achievement of their own tasks at their own responsibility.

Although both aspects of reality are essential for learning, the authors would like to emphasize the importance of social reality rather than perceptual reality. Regarding perceptual reality, recent progress in computer technology has improved the learning media to a considerable extent. However, it still depends on the expertise of experienced educators to produce learning activities that are rich in social reality. Therefore, we are convinced of the necessity to develop a design methodology for the social setting of a learning environment allowing the accomplishment of social reality.

From the reasons mentioned above, the authors have tried to design a social setting using the constraints provided by learning tools, such that students, wishing to establish their identities in the community, will be able to work on practices to achieve their own tasks at their own risk, and not solely to maintain a good relationship with their teacher.

Table 1. List of reserved words in the programming language.

action commands	move_forward move_back bend_forward bend_back step_forward step_back throw slap_down push_forward grasp_mawashi disturb_hishand release_mawashi wait
system variables	my_position his_position distance my_posture his_posture my_arm his_arm upper_arm my_leg his_leg
commands and special symbols	if ifelse select endselect case caseelse repeat while until to end stop stopall make local table tmake search and or not # + - * / > < >= <= =

2. AlgoArena: a tool for learning software design

2.1. Discussions on student's activities

AlgoArena [2] is an introductory tool to teach software design to beginners. The authors focus on developing the algorithmic way of thinking and a systematic view of things through problem-solving activities, rather than just teaching a specific programming language.

AlgoArena is a simulation game of sumo wrestling — the traditional Japanese national sport. Students are supposed to program the actions of their own wrestler using a LOGO-based programming language to win matches against other wrestlers.

In the AlgoArena system, some constraints for the social setting of the learning environment are incorporated, so that students can form their community of practice and facilitate social interaction. For example, ① Using the constraint that a player needs opponents to fight with, students are encouraged to have matches with others, and social interaction among students are facilitated; ② Using the constraint that one wins while the other loses, the player's will to win is evoked, and students come to share a common purpose — to try to win — and a common sense of values; ③ Using systematic match organization, such as tournaments or leagues, students are able to have an exciting time together, fostering the sense of community; and ④ Using a definite game system that requires deep thought, which will be mentioned later, the community is kept lasting and evolutive. In this way, AlgoArena can help to form a student's community.

Regarding activities in the game, students are encouraged to systematically analyze why they lost, to plan tactics to win, and to implement them into the programs, while simultaneously keeping various constraints in balance. These comprehensive problem-solving activities are comparable to authentic activities in software design, i.e., in analyzing situations, defining problems to solve, devising ways to solve them, and implementing them into the program. Furthermore, what is important here is to what and how students commit through those activities. In AlgoArena, students tend to commit to solve their own problems to establish their own identities in the community at their own risk, rather than commit to a teacher for learning. This is also comparable to the authentic activities of programmers, who are socially motivated and are responsible within the context of solving the specific problem to which they are committed. In this sense, activities using AlgoArena have a high social reality, and can thus be regarded as a significant 'epitome' of authentic software design.

This stands in contrast to the conventional way of teaching software design. A typical course consists of instructions and discontinuous exercises, where solving problems is not valuable in itself, but is valuable only for the purpose of education. This is because they are usually problems that have already been solved. In addition, since problems are presented in a well structured and specifically defined form, students do not have to analyze chaotic states of affairs to find out the problem they need to solve. Consequently, students are more inclined to commit to the teacher for 'learning' than undertake problem-solving itself. From this, the authors would say that the conventional way lacks social reality as well as essential portions of authentic cultural practice.

AlgoArena is designed to be the core of the student's community, in which students practice software design. It does not explicitly tutor like a conventional CAI, nor implicitly embed what is to be learned as principles of the virtual world like a conventional microworld. However, it serves the arena where students apply what they have learned. Students learn mainly through social interaction with a teacher and peers, rather than solely through interaction with a computer.

2.2. AlgoArena System Overview

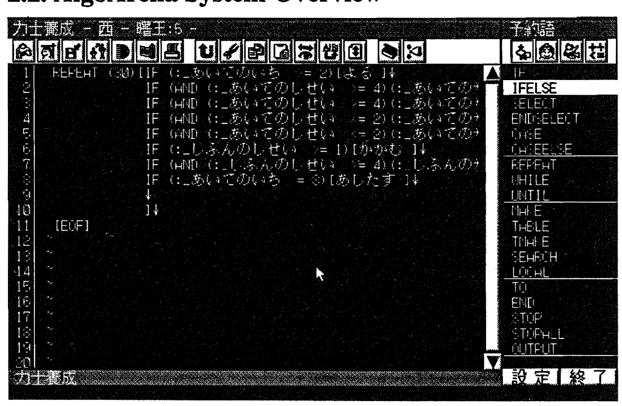

Figure 2. Screen editor incorporated in AlgoArena.

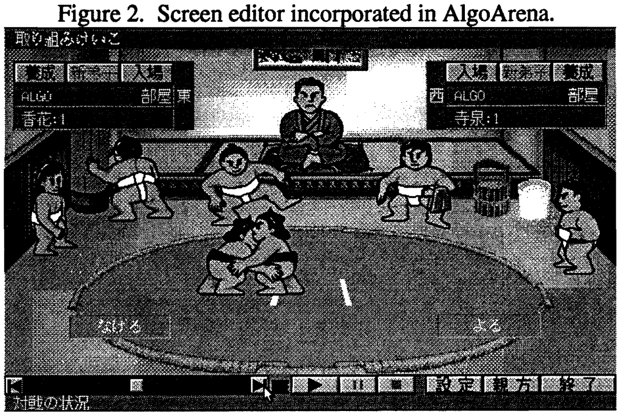

Figure 3. Fighting scene of AlgoArena.

```
REPEAT 30[
    IFELSE (:_my_position = 8)
        [move_forward]
        [IFELSE (:_his_posture = 4)
            [slap_down]
            [push_forward]]]
```

Figure 4. Example of a program.
(Some parts translated into English)

AlgoArena is a simulation of a sumo bout. A student (player) has his/her own wrestler, and makes a program describing the wrestler's actions with a screen editor, as shown in Figure 2. The editor is designed so that beginners can enter almost all the reserved words (commands, special symbols, system variables, and so on, as shown in Table 1) just by clicking on the menu. The student then lets his/her wrestler fight with opponents programmed by other students or teachers. The fighting animation is seen on the graphic screen of the monitor (Figure 3). The student is supposed to analyze the fight, find out the causes for defeat, devise tactics, and incorporate these into the program. Another cycle of activities is regenerated by a return match. Through these cyclic activities, students are expected to develop comprehensive capabilities for the basics of software design.

Figure 4 shows an example of a program. The program repeats the following thirty times: if my wrestler is on the edge of the ring (`my_position = 8`), let him go forward; if not and the opponent is bent far forward (`his_posture = 4`), then slap the opponent down; otherwise push the opponent forward.

The game of AlgoArena continues as follows. Either of the programs runs, referring to the current states of the game, determines the subsequent action command, and stops when this is determined. The other runs in the same way. When a pair of action commands is determined, it is evaluated at once. This is so that the first mover will not have a (dis)advantage. According to the combinations of the commands and the current states of the game, the game status change. The match ends when the conditions of the two wrestlers are such that one of them wins. If a match is not won by either wrestler after thirty sets of action, it is declared a draw.

The system of the game is definite, i.e., no element of chance is allowed to affect the outcome of the match. Therefore, the same match always follows the same process, and a match between identical wrestlers never fails to end in a draw. Since there is little chance to win by accident, deep thought is required for a sure win. Consequently, as student's capabilities in software design improve, the wrestler gets stronger.

2.3. Experience from an exploratory case study

The authors ran a pilot experiment at a municipal junior high school. The subjects were 27 students, aged from 13 to 15, and classes were held once a week for 6 weeks; each class was 50 minutes long. Most of the class time was spent making programs. Oral explanations were principally limited to system operation and sample program behavior. Apart from this, a manual of programming commands was distributed. Students were expected to learn by talking with others, as well as by looking at sample programs.

According to the answers to the questions after the classes: "What was interesting in AlgoArena?", the most frequent answer (41%) was "to have matches with friends." The answer to the question: "Who do you prefer to fight with?" was in 19% of cases 'programs made by peers', 4% preferred 'pre-installed sample programs', and 52% preferred 'both of them'. These results show that students were mainly motivated by social interaction with others. In addition, in the answer to the question: "With whom did you consult on programming? Name them.", 78% of students named consultation with peers. This result and our observation show they actively communicate with one another. Consequently, it seems plausible that a community of students, in which they are keen on problem-solving activities toward a common goal, was successfully formed.

Regarding performance of learning, almost all (96%) understood the usage of `REPEAT` and `IF` correctly. In the junior high school, BASIC language class is mandatory in the 9th grade and one of its goals is for students to understand the usage of `FOR..NEXT` and `IF` after 9 to 10 class hours. Compared with this, almost all students using AlgoArena reached this level in a shorter (less than 2/3) time. In particular, the class teacher reported that he was surprised to see a certain student of the lowest ability working on the activities very aggressively, and he created a program of nearly average level.

3. Conclusion

The design principles and system overview of AlgoArena are presented in this paper. The game situation incorporated into AlgoArena can provide students with a social setting that they commit to problem-solving itself at their own risk. It is comparable to the authentic activities of programmers. In this sense, activities in AlgoArena have high social reality. The exploratory case study revealed that a community of practice was able to be formed successfully and students enjoyed the social interaction with others. Moreover, learning performance reached the same level as that for conventional methods in a shorter time.

The authors will look into more cases to examine interaction among students and how they develop their community of practice.

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Identifying the Support Needed in Computer-*Supported* Collaborative Learning Systems

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Abstract

Computer-supported collaborative learning (CSCL) systems hold the potential to enhance the effectiveness of peer learning interactions, assuming that these systems are truly *supportive*—i.e., capable of coaching collaborating peers as they work on problems and critique other students' solutions. We argue that in order to achieve this goal, CSCL system developers need to know more about the types of coaching that students are typically able to provide to each other during problem-solving activities, and what types of advice they need from more experienced students or "mentors" at various stages of their development in the instructional domain. CSCL system developers also need to know how *human* mentors provide such coaching, and—based on this information—to develop computer models of human guidance during collaborative interactions. We describe a pilot study (in progress) whose goals are to address these issues and to assess the effectiveness of the research methodology we devised for doing so.

Keywords — Technological developments for CSCL, problem solving, theories of collaboration and learning.

1. Introduction

Collaborative use of instructional systems can take on a variety of forms—from two or more students working on problems at the same computer workstation, using a tutoring system that was primarily designed with an individual user in mind, to peer collaboration on systems which were specially tailored for use by multiple learners working at the same workstation or across networked machines. The latter are typically called *computer-supported collaborative learning (CSCL)* systems, since they are intended to "scaffold" or *support* students in working together productively. Various types of support can be provided by these systems, including utilities for communicating ideas and information, facilities to access documents and other types of information, advice during problem-solving activities, etc.. The type of support that we focus on in this paper is advice during problem solving.

But why scaffold collaborative problem solving? Despite an abundance of studies showing that social learning situations correlate with a wide range of positive outcomes—including greater learning, increased productivity, more time on task, transfer of knowledge to related tasks, higher motivation, and heightened sense of competence (e.g., Slavin, 1990)—there is also widely recognized room for improvement. Collaborative learning does not work for all learners, and the results of instructional outcome studies are mixed (Webb, 1987). Fruitful student interactions are simply not a given. In Brown and Palincsar's (1989) words:

> *Social interactions do not always create new learning; peer interactions vary enormously; only some teaching environments actually create ideal learning experiences.* (p. 397)

Thus, one of the prime factors motivating the development of CSCL systems is to improve the effectiveness of collaborative learning as an instructional format (e.g., McManus & Aiken, 1993); to "create ideal learning experiences," as Brown and Palincsar invite instructional designers to achieve.

In recent years, several researchers have attempted to find out what makes some peer interactions successful but not others. One important line of research has focused on verbal exchanges during group work (e.g., King, 1989; Webb 1987, 1989). This work converges on an important finding: i.e., that the *nature of peer interactions* is perhaps the most critical factor mediating individual student achievement. As Webb and her colleagues have consistently shown through over a decade of research on peer interactions in computer-based and non-computer-based settings, "students learn more by giving elaborated help to others and learn less by receiving low-level elaboration from others" (Webb & Farrivar, 1993). However, unelaborated explanations or "terminal responses" are more typical of student responses than are such "high quality explanations"—at least among school-aged children (e.g., Webb, 1989). Not surprisingly, research by King (1989) shows that another important interaction skill which students often lack is the ability to ask questions which evoke elaborated explanations.

The results of this research on the relation between the nature of peer interactions and learning are important for developers of CSCL systems, because they suggest that these systems should scaffold the production of high-level questions and elaborated explanations. However, the research done to date is weak in accounting for when and how—i.e., in what *contexts*—peer question-asking and explanation failures occur. Various issues need to be addressed in order to tailor advice in CSCL systems according to the advising capabilities of the target users, such as: Are students uniformly and consistently poor at giving explanations, or do they tend to explain some types of knowledge more readily than other types—e.g., procedural knowledge as opposed to conceptual or strategic/planning knowledge? To what extent are explanation failures correlated with (and perhaps indicative of) knowledge gaps? As knowledge and skill in the task domain increases, does the quality of explanations (and questions) improve? How do collaborating peers use the various information and advising resources available to them in a learning environment? How do human mentors scaffold collaborating students during impasses—e.g., when is mentors' support directive; when is it more dialectical? With these research issues in mind, we observed and videotaped students as they worked together on **Sherlock II** (e.g., Lesgold et al., 1992), a computer-based, coached practice environment developed to train U.S. Air Force avionics technicians to diagnose electronic faults in F15 aircraft modules and in the complex testing systems used to check out these modules. Our principle aims in this pilot study are to: (1) capture the nature of peer learning interactions in this problem-solving domain, in terms of the issues raised above, (2) determine the extent to which the findings derived from this analysis could inform the development of effective advising capabilities in a collaborative version of **Sherlock II**, and (3) assess the effectiveness of our research methodology for accomplishing the preceding objectives. The data collection phase of the study is completed, and we have started to analyze the data. In this paper, we describe the pilot study and the data that it has yielded.

2. Description of the Pilot Study

2.1. Research Context

Like its predecessor, **Sherlock**, **Sherlock II** is a coached practice environment. It provides a realistic computer simulation of the actual job environment, allowing students to make measurements, interpret readings, replace suspect components with shop standards, etc., until they have isolated the faulty component. Students thus acquire and practice skills in a context similar to the real context in which they will be used. Advice is available "on demand" throughout problem solving. After solving a problem, students enter a review phase which we call Reflective Follow-up (RFU). During RFU, students can step through their solution with feedback from the computer coach, ask to see a sample expert solution, get advice for their next session, and review the standards of effective troubleshooting. In other words, RFU "debriefs" students on their performance.

2.2. Subjects

Three groups of people participated in this pilot study of peer interaction in a coached practice environment. First, eight experienced avionics technicians from local (Pittsburgh-based) Air National Guard and Air Force Reserve units served as *mentors*. Among these mentors, on-the-job experience in avionics ranged from three to twenty years (7.5 years was the mean). The second group of participants consisted of 16 *avionics students* (forming eight dyads) from two local avionics technical schools. All but three avionics students were in their final term of a six-term program; the other three were in their fifth term. Finally, four *Air Force ROTC students* (forming two dyads) also served as subjects. All eight mentors, and all but two of the twenty students, were male. Subjects volunteered to participate, and were payed a nominal amount.

2.3. Procedure

Following an orientation to the **Sherlock II** task domain and practice with using the tutor, all but two of the ten dyads were assigned to a mentor, who worked with the same dyad for one two-hour session per week. All dyads worked on the same set of **Sherlock II** problems, in the same order. There were two phases of data collection. In the first phase, students worked together at the same computer, doing one or two problems per session. One student was assigned the role of problem solver; the other student was assigned the role of "coach." These roles were reversed for each successive problem, in *reciprocal teaching* fashion (Palincsar & Brown, 1984). Students were directed to ask their peer for advice first, to use Sherlock (the computer coach) if their peer could not answer their question (or answer it adequately), and to ask the human mentor if they were still stuck or had a question about something in Sherlock's message. In this way, requests for "external" (i.e. non-peer-provided) coaching will be clearly marked in the data, allowing us to readily identify instances of peer coaching failures.

The human mentor observed the students' actions from a networked machine. Although the two machines were in the same room, students were directed not to talk to their mentor. Instead, students were asked to pretend that they were avionics technicians stationed in Alaska, while their mentor was in Hawaii; their only form of communication was via a teletyping window on their and their mentor's screen. Since one of our main goals is to capture how mentors scaffold students when the latter are unable to coach each other during collaborative work, we placed one restriction on mentors' behavior: we asked them to let students try to help each other first, and to initiate advice only when the mentors thought that doing so would prevent students from "going down the garden path." We also told mentors that one way they could respond to students' queries was by suggesting that students access one of Sherlock's coaching options.

As illustrated in Figure 1, the teletyped communication between students and their human mentor was automatically recorded and integrated with the transcript of student actions that the system generates during problem-solving sessions. These transcripts will allow us to analyze students' interactions with their human mentor in the context of students' problem-solving actions.

The first phase of data collection, combining videotaped with teletyped recording of dyad-mentor dialogues, lasted for two sessions per dyad. During the second phase of data collection, students worked at *separate* machines. As before, one student acted as problem solver, the other student as "coach." However, communication was entirely through the teletyping mechanism described above, which students used during phase one to communicate with the human mentor. During this data collection phase, the human mentor's role was explicitly to "coach the student coach." The mentor and student coach did this via teletype, using a second keyboard that was connected to the student coach's machine. When the student coach was unable to respond to his peer's request for help, he could carry out a teletyped dialogue with the mentor until he reached the point where he could advise his peer. When this happened, he transmitted the dialogue he had with his mentor to the student solving the problem. In order to be able to distinguish in the transcripts between the dialogue contributions of the mentor and the student coach, the mentor typed in capital letters; the student coach typed in regular font. This second phase of data collection consisted of four sessions per dyad.

We separated data collection into these phases for two reasons. First, we want to be able to compare videotaping with teletyped communication for studying dyadic interaction, and human mentors' support for the same, in computer-based learning environments. In particular, to what extent, and in what ways, does teletyping reduce the communication bandwidth? Does the convenience and contextualization provided by the automated transcripts compensate for the reduced bandwidth of teletyped communication? Second, several of the students and a few of the mentors were poor typists. So, in order to prevent "cognitive overload," we tried to minimize the amount of typing that they would have to do during early sessions, when they were still getting comfortable with the **Sherlock II** task domain and user interface. By the third session, students were adept enough **Sherlock II** users to communicate with each other via teletype, although it was somewhat "slow-going" for the poorest typists.

3. Conclusion

Several researchers have been developing instructional software which is specially tailored for collaborative use —i.e., CSCL systems. However, very few CSCL systems are being built in such a way that the advising resources available to students are based on empirical research on what students actually do, and fail to do, while they collaborate. [Baker and Bielaczyc's (1995) research in identifying "missed opportunities" (MOs) for conceptual development when students work together in the context of the CHENE CSCL system is a notable exception.] We believe that CSCL environments hold the potential to enhance the effectiveness of peer learning interactions, assuming that these systems are truly *supportive*—i.e., capable of coaching collaborating peers as they work on problems and critique other students' solutions. In order to achieve this goal, system developers need to know more about the types of coaching that students are typically able to provide to each other during problem-solving activities, and what types of coaching they need from more experienced students or teachers at various stages of their development in the instructional domain. System developers also need to know how *human* mentors provide such coaching, and—based on this information—to develop computer models of human guidance during collaborative interactions. The pilot study described in this paper aims to address these issues, and to assess the effectiveness of the research methodology we devised for doing so. We look forward to reporting on the findings that emerge from the data analysis phase of this work.

The students' dialogue contributions are flagged by an **Event** labelled STUDENT MESSAGE. The mentor's contributions are labelled as COACH'S MESSAGE. Dialogue text is in *italics* and is unedited. Comments are in **boldface**. Ellipses signify deleted segments of the transcript.

...

****

The students reach an impasse (i.e., they are unable to help each other), and pose a question to their mentor (Brian).

Time: (2 May 1995 7:39:30 pm)

Event: STUDENT MESSAGE

Text: *"bryan, do we assume that the relay card is getting pwr [sic; should read "power] or would it be a good idea to test it?"*

****

The mentor replies.

Time: (2 May 1995 7:39:51 pm)

Event: COACH'S MESSAGE

Text: *"NEVER assume anything!!! you should verify that the card is bad by checking inputs, outputs, and data controls signals"*

****

...

The students set up the handheld meter, and make a few measurements.

Time: (2 May 1995 7:42:39 pm)

Event: MEASUREMENT taken.

Device: HHM

Red Probe: 33

Black Probe: 30

Reading: 0.0000 Vdc

****

Figure 1: Computer-generated transcript of a collaborating dyad communicating with a mentor across networked machines

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Computer Representations in Students' Conversations: Analysis of Discourse in Small Laboratory Groups

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Abstract

Language use in student laboratory groups makes apparent students' conceptions in science, their interpretation of the activity/task, and the negotiation of the roles of the members. This paper reports on a methodological approach to systematically analyze student discourse. Four grade-12 lab groups working on microcomputer-based laboratories (MBL) are the focus of the study. The MBL experiences were used to help students link oscillatory motion to graphical representations. Study of student discourse reveals the role the computer plays in the group context and the ways that this context is shaped by the computer. Developing a better understanding of the role of the computer in student conversations suggests ways to fruitfully construct contexts for learning physics.

Keywords — microcomputer-based laboratories (MBL), physics, discourse, science education.

1. Introduction

A conceptual understanding of science is typically sought among educators. We argue that focusing on language provides us with an interpretative lens to understand both what gets accomplished in small laboratory groups as well as how it is accomplished. Learning science includes constructing understandings that are consistent with empirical evidence and the theoretical backdrop of a discipline. MBL experiments allow students the possibility of interacting with the physical world and simultaneously reacting to representations of these events. This provides a unique setting for studying students' conversations.

2. Language and science learning

Learning science requires novices to be initiated into the conceptual frameworks, epistemic dispositions, and social practices of the scientific community. The central conceptual frameworks of a discipline allow a community to identify problems to be solved, to decide on what will count as a solution, and even to experience certain events (Strike, 1982). In order to participate in the ongoing conversation of a community, students/novices need to understand how the community operates, what language is used, and how evidence is evaluated. Educational contexts must be formed so that students get an understanding of what it takes to participate within the scientific community. Central to the processes of constructing scientific knowledge are the social and discursive methods used to establish a claim (Latour & Woolgar, 1986). Both experimental and theoretical evidence need to be articulated in persuasive arguments to a relevant epistemic community before it is acknowledged as scientific knowledge. In order to understand the socially derived knowledge of a community of knowers, novices need to participate in conversations and "forms of life" of the community (Wittgenstein, 1958). The processes used by students to come to know the use of scientific concepts needs to be documented to better understand how to construct appropriate educational contexts.

2.1. Sociocultural view

Sociology of science documents the problematic nature of scientific inquiry. The social processes of constructing scientific knowledge are central to establishing a claim (Collins & Pinch, 1993; Kelly, Carlsen, & Cunningham, 1993). For example, discoveries in science are typically made retroactively by a community of scientists (Brannigan, 1981). Discoveries do not happen as a specified "event." Rather, over a long period of data collection and analysis, the facts are constructed through discursive processes (Woolgar, 1980).

The empirical evidence plays only a partial role in establishing a scientific fact. Similarly, students are not compelled solely by empirical evidence to accept scientific theories. Students' ideas are formed in a social context an example of which is science laboratory experiments. Students need to see that deliberative aspects of science are as important as collecting data. As with scientists, students' discoveries are a process; ideas are constructed, debated, and reformulated. Students need to be able to formulate conceptions, explanations, and hypotheses, submit these ideas to empirical and deliberative tests, and reformulate them as necessary. The MBL experience studied here was designed to engage the students in conversations about physical phenomenon thus giving them the chance to "talk science" (Lemke, 1990). The choice of educational setting for examining these processes becomes crucial. We sought an educational context where students could use empirical evidence and practice talking science. Microcomputer-based laboratories provided both of these qualities.

2.2. Microcomputer-based laboratories

Microcomputer-based laboratories offer students the opportunity to engage in the discursive process of creating meaning in collaborative laboratory groups. MBL protocols differ from typical laboratory experiences in that students can quickly acquire and analyze data. Cycles of data acquisition, analysis, discussion, and reframing of the research question can be created. Furthermore, data acquired in real-time can be viewed in multiple representations (events, graphs, tables, equations) and manipulated to answer student questions. The MBL setting thus is thus methodologically interesting because the computer offers representations that must be interpreted by the students (Roth, 1995). Students need to talk curves and squiggles into concepts and ideas.

2.3. Research site and educational context

The study was conducted in a rural high school in California undergoing the process of systematic school reform. The students enrolled in grade-12 Advanced Placement physics course are the subjects of this study. During the episodes studied, the students worked in collaborative laboratory groups of 3 or 4. The students were guided through a lab protocol to study oscillatory motion. The technology was configured as shown below in Figure 1.

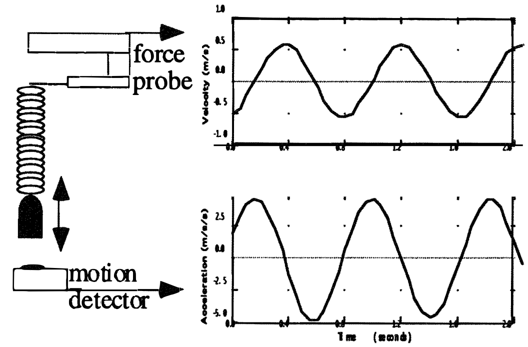

Figure 1. Experimental configuration. Pictured is the mass on a spring, a force probe, and a motion detector. The force probe and motion detector both send electronic signals to an interface box and the computer generates graphical representations as shown on the right. Representative graphs generated by MBL acquisition software (Vernier Software MacMotion Version 4.03).

3. Methodology

Students' words and actions while working in the laboratory groups were captured on videotape. Each of the four 45 minute group sessions was analyzed on multiple levels building on the methodology of classroom discourse (Green & Wallat, 1981; Bloome & Egan-Robertson, 1993). First, we broke down the episodes in detail in order to understand how the conversation was being created by the actors (students, teacher, researcher, and computer). Second, we identified the ways these smallest building blocks were put together by the actors to form larger structures. We then used these larger units to identify patterns of interaction.

3.1. Student discourse

We analyzed the episodes at multiple levels. First, we identified *message units*. Messages units are defined boundaries of utterances or social action. Message units are the smallest unit of linguistic meaning and must be identified post hoc by cues to contextualization (Gumperz, 1992). This was done both from the audio dub but also directly from the videotape as the non-verbal cues are important in identifying the message units. Figure 2 is a representative portion of a transcript. This group is comprised of three human members and the computer. The transcript starts with L saying, "that is really neat." This is a complete message unit. Nancy then gives direction to Laura, "do big circles." Nancy's first message unit is separated by only a very short pause before her next message unit, "jump up and down" is given. On the transcript, each message unit is on a separate line.

Second, we identified the actors' *action units* which are comprised of one or more message units. Action units often show a semantic relationship among messages and represent an intended act by a group member. These are likewise identified *post hoc*. Action units make visible the thinking students choose to display publicly. This level of analysis provided us with the opportunity to see how the computer representations entered the students' conversations. For example, N's two message units, "do big circles," "jump up and down," are tied as one action unit. She is giving a directive to Laura. The action completes her task of telling Laura how to move so that another experimental run can be completed. The third and fourth levels are not relevant to the interpretations described below.

	transcript	codes
L:	that is really neat	responding
N:	do big circles	
	jump up and down	
C:	*produces representation*	responding
N:	so why does it go lower?	clarification
	distance versus time	demonstrating
	so when you get closer	claiming
	it goes	"
	further this way?	"
	=no that's time=	demonstrating
S:	=no that's probably	claiming
	just how far	
L:	that's time	
S:	how far	
	it is away	
N:	time is that	claiming
	and	
	and	
	distance is	
	this	
	when you're that close	
	you go crazy	
	go crazy far away	

Figure 2. Representative transcript of students' conversation in MBL context (L, N, S are students, C is the computer).

3.2. Patterns of interaction

The research methodology of following closely the students' conversation in the laboratory setting makes visible patterns of interaction. In this paper we report on just one of these: the use of computer representations in student conversations. Throughout our analysis of student discourse we were able to recognize the multiple uses of the computer by the student group members. After analyzing the student discourse at the level of action units, we reviewed again the videotape and noted each instance that a computer representation was produced or that a student specifically employed a computer representation in the conversation. Each of these instances was coded based on how the reference fit into the larger conversation. Figure 2 shows how the analysis of student discourse allows for the identification of interactional patterns on a representative piece of transcript. In each case the computer representation enters the conversation in one of the two ways described below.

There are two pathways in which the computer representations enter into the group conversations. In the first case (Pathway 1), the computer creates a representation of acquired data (see Figure 3). This representation must be interpreted by student(s) to become a message in the conversation. Typically, these messages provide information regarding a physical event.

Reciprocally, these messages can be become interpreted representations that enter the conversation through pathway 2. In this case (pathway 2), a student employs an interpreted representation (the computer message) for support in her argument or explanation. The new message is used now by the student for the purpose of supporting her own conceptions. Our claim is not that the two pathways represent mutually exclusive entrees into the conversation. Rather, the difference is one of perspective. We can choose to see the computer operating as a member, or alternatively, as being employed by other members in the conversation. Thus, for each way the computer acts as a member, there corresponds instances of students employing the computer representation. The computer must be recognized in order to participate.

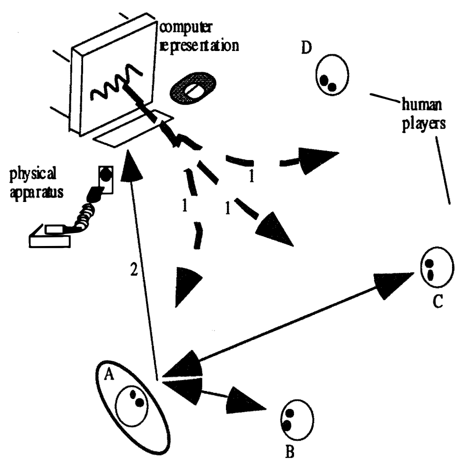

Figure 3. Pathways of computer entree into conversation. Through pathway 1 a representation is made available for the students. In Pathway 2 a student acknowledges the computer representation, in this case by making a case to other students by employing the representation.

Computer representations enter through pathway 1 in multiple ways. A means-end domain analysis (Spradley, 1980) of the entrance of these representations into the conversations shows five distinct avenues of entree. (a) The computer *enters as an ally* for one or more students in their effort to make a case. One way the computer acts as an ally is by providing the possibility of a successful prediction. (b) The computer acts to *help construct meaning* in the group; there is an explicit appeal to the computer. Students demonstrate an event or events to others by drawing attention to a specific piece of data. (c) The computer *exhibits* vital information. Data crucial to the point being made in the conversation is exhibited on the computer screen. (d) The computer *elicits* students responses. These responses can be exclamatory ("cool," "neat," or "what?"). (e) The computer presents students with *anomalies* to the students' expectations or conceptual frameworks.

Similarly, students used the interpreted computer representation entering through Pathway 2 in seven ways. We used means-end domain analysis to categorize the seven ways these representations were employed in the student conversation (see Figure 3). For each of these student uses of the computer representation, there is a reciprocal relationship with the computer acting as a member. The seven uses of the representations by students are: (a) The computer representation is used by students to make a *claim*. The representation thus becomes a piece of evidence supporting a larger student argument. In order to be a claim, we required that the student action linked a real event to a representation. See Figure 2. (b) The computer is employed by students as they make *predictions*. They suggest that the computer will give a particular result given certain circumstances. (c) Students bring in the computer by *demonstrating* a particular feature of a representation. Typically, students seek to demonstrate the location of a specific aspect of the representation on the screen. A typical example would be "distance versus time" (See Figure 2). In this case N points to the axes by moving the mouse (and arrow on the screen) to bring the attention of the other group members to this portion of the representation. (d) Students look for the computer to make sense of physical phenomenon, coded as *looking for clarification*. Physics concepts may be initially inaccessible to the students. An example is provided on Figure 2 where N asks, "so why does it lower?" (e) Students find information on the computer screen, coded as *reading*. Students may be reading numbers or information from the computer screen. (f) The students also *respond* to the computer as a member in the group. When the computer gives a representation it's treated by students as a utterance in need of response. L responds to the computer "that is really neat" in Figure 2. (g) Students *recognize anomalies* to either their own initial conceptions or to the expected result of an experiment based on the standard physics account.

4. Conclusion

The results of this project reveal both how the computer enters into students' conversations about physics and the importance of focusing on student discourse in the computer learning setting. Above we've described two pathways for computer entree into a conversation. Throughout these episodes of computer/student talk there exists an interchange as students seek support from the computer and the computer offers support to the students. The detailed analysis of looking closely at student discourse demonstrates the role a computer can have in the social and conceptual interactions of collaborative lab groups. The computer is thus best interpreted as a member in the group and conversation. Nevertheless, the computer has a special dual status in the group. The computer representations are meaningless without student mediation. Computer representations must be brought into the conversation through the interpretative lens of a student. In this way the computer has a lower status as a partner. However, the computer has access to the empirical data the students are seeking to understand. This elevates the computer to "judge of appeals," and a privileged status. The appeals to the computer can be variously interpreted and aren't decisive. Resolution lies entirely within the lab group interactions.

The analysis we presented above provides a way of seeing what gets accomplished through language in small laboratory groups. We provided evidence of how the four groups employed the computer and made the computer a member of the group. This analysis can now be extended to compare across groups and across time within a group. Such comparisons would help us further understand student actions and how these may be related to our goals of conceptual understanding in science education. The processes engaged in by students to play the language games of science can be revealed through this analytical procedure.

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A Classroom Study: Electronic Games Engage Children As Researchers

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Abstract

This paper describes the authors' experiences in using classroom play of electronic games as a central component of a collaborative approach to mathematics learning in a grade four classroom. The authors form one of the pairings (computer scientist, elementary teacher) of university researchers with teachers, in the E-GEMS classroom study, an ongoing long-term qualitative study on the potential uses of electronic games and activities for enhancing mathematics learning in intermediate grade classrooms. We believe the experiences from this study can provide insight on issues of importance to research on computer-supported collaborative learning in the classroom and to mathematics education.

Our experiences echo those of many others on the effectiveness of collaborative use of computers, where the collaboration occurs through small groups of learners working at each computer. We also note the positive impact of connecting the computer activities with related large and small group classroom activities. We are excited by the success of these approaches in stimulating students to talk and write about mathematical concepts, and to view themselves as researchers exploring mathematical ideas. Finally, our experiences reinforce the need to re-examine user-interfaces and other areas in human-computer interaction in the context of computer-supported learning. A more detailed version of this paper is available from the authors.

Keywords — Human-Computer Interaction, Computer-Supported Collaborative Learning, Electronic Games, Mathematics Education, Classroom Strategies.

1. Introduction

The classroom study forms one component of the Electronic Games for Education in Math and Science (E-GEMS) project, a large-scale initiative among the University of British Columbia, Electronic Arts, Queen's University, Apple Canada, several elementary schools, and Science World BC. Other components of E-GEMS include basic research on children's interactions with electronic environments [4, 5], shorter term studies on specific issues related to the use of electronic games in education [2, 3], development and evaluation of prototype electronic games and activities for mathematics education, and the design of commercial electronic games for mathematics education. The first such commercial product, Counting on Frank, was published by EA*Kids in late 1994.

Our reasons for investigating electronic games as an ingredient in mathematics education were their attractiveness to many children, their exploratory and interactive nature, and the ability of electronic environments to facilitate concept visualizations and manipulations that are difficult to achieve with concrete materials. Despite these positive factors, we questioned whether the playing of electronic games, on its own, could bring about other essential components of effective mathematics learning such as reflection and ability to transfer the learning to other contexts. One of the primary goals for the classroom study is to investigate strategies that address this concern. Like others in working in mathematics education [1, 6] we believe that verbal and written discourse are highly effective in stimulating reflection, and that ability to transfer is enhanced by experiencing the learning in multiple modes and contexts. Thus we have focused on strategies that combine playing electronic math games with speaking and writing about mathematics, and with other mathematics activities away from the computer. Our approach uses the playing of games as an integral component of mathematics learning, rather than as a way to trick students into paying attention before the "real teaching" starts, or as a reward for students who finish their work early. The classroom study also influences the other components of E-GEMS, guiding the direction of basic research activities, identifying critical issues, and providing a test-bed for evaluation of prototype games and activities.

The study is being conducted in the classrooms of four teachers in four different schools, three in Vancouver and one in Kingston, Ontario. The teachers (and their schools) were chosen to have some characteristics in common, and to differ in others. Their common characteristics include a commitment to collaborative learning, an interest in participating in research projects, and a reputation as being a good teacher. The teachers differ dramatically in their length of time in teaching (from 4 to 24 years), their comfort in using computers (from computer-phobe to computer-lover), and in their approach to teaching mathematics (from primarily textbook-based to virtually no use of a textbook at all). Their classes also differ in many respects: grade level (from grade 3-4 to grade 7-8), socio-economic status, proficiency in English language (ESL, French immersion, fluent).

The study began in mid-March of 94 with the placement of four LC III Macintosh computers in each classroom. The computers were equipped with a fairly limited selection of software: a word processor and paint program designed for children (Microsoft's Creative Writer and Fine Artist), Hypercard, and E-GEMS prototype games. CD-ROM drives were gradually added, together with a small number of commercial electronic games (The Incredible Machine by Sierra Dynamix, Counting on Frank by EA*Kids). Each teacher established a schedule for the students to use the computer, and encouraged the students to keep a journal of their experiences in using the computer. Because of our interest in collaborative use of computers, the schedules were designed to allow 6-8 students access to the 4 computers at once. In some classrooms students also use the computers during "free-time": recess, lunch, and before and after school.

Each classroom was assigned an E-GEMS university researcher to visit the classroom weekly for one to two hours. During such visits the researcher's activities include observing the students using the computers, interviewing students, and participating in discussions with the whole class about the electronic games and other activities. The Vancouver teachers also participate in monthly meetings, where the teachers and their university partners get together to share their experiences, and to help advise on other E-GEMS research efforts.

2. Students As Researchers

The E-GEMS teachers have used a variety of strategies to emphasize the "student as researcher" approach. We have found this approach to be particularly effective in engaging students' interest in using the computers. When the "student as researcher" emphasis is not present in a classroom for a few weeks, as has occurred in each classroom for a variety for reasons, many students ignore the computers during that time. We consistently find that students choose to play the games that they are guided to play, and the games that are mediated. As others before us have observed, a computer put into a classroom is not a magical thing. It will not, by itself, attract students to the world of learning, or even to the world of games.

In Eileen's classroom, the students are introduced to their role as researchers early in the year. The major research formats used are journal keeping, sign-up charts, tally charts of games played, maintaining "bug" sheets, and weekly class debriefing/sharing sessions. Journal entries serve several purposes. They give a clear record of what activities the students are engaging in; they also let us see whether students are static or changing in their choice of partners. From their writing we learn how students interact with the computers and each other, from how they delegate control of the mouse to what they learn from each other.

The sign-up charts ensure that all students have access to the computers each week. Students sign-up for two periods weekly. This sign-up has been done three times during the course of the year to promote different student groupings. Journal entries and tallying of activities are made in conjunction with sign-up times. The bug sheets are used to record problems the students find in the E-GEMS prototype games. These prototypes are placed in the classrooms beginning in very early stages of development. The university researchers responsible for prototype development then visit the classroom regularly to discuss the games with the students, pickup the bug sheets, and install the latest versions. The students love their role as bug-finders and expert critics. They quickly learn the value of making detailed observations when a problem occurs. They also see they are genuinely respected as researchers.

One of the most effective strategies we have found is the holding of regular whole class debriefing/sharing discussions. In Eileen's classroom the initiation of these meetings marked a significant change in student attitudes. Once regular recording and sharing of ideas was expected, the students started to really listen to each other, to write more detailed comments about their findings, and to think not only about what they were doing, but also about what they were learning. For us, this is of crucial importance. Like many teachers, Eileen is particularly interested in methods that provide her with windows into students' thinking. Her class is very good at verbalizing their ideas. They are weaker at written discourse. For Grade 4 students, it is often onerous to have to write things that are so much more easily shared orally. However, writing about computer research, although not everybody's favorite, is something that they all do.

Recently, when Eileen asked her class to tell her what they knew about being researchers, two ideas kept coming up. "Research is hard and research is fun." At the beginning of the year, these same students were convinced that the only work that was fun was easy stuff. The words "hard and fun" were never spoken in the same breath.

3. Pencil and Paper Game Explorations

Another important component of our classroom research is trying out pencil and paper activities related to the computer games. The EA*Kids CD ROM, Counting on Frank, has four groups of math games which the player may choose to play separately from the overall game. We have used each of the math games as the basis for an activity in which the students work with variants of the game. These activities stimulate students to explore the electronic versions of the games more fully, and provide a clear connection between the computer and pencil and paper approaches to mathematics. They also give students the experience of enjoying themselves while working on mathematical challenges they find difficult. We illustrate these points by describing one of the activities.

The simplest version in one of the four groups of games in Counting on Frank is 9-or-bust, a two player game played on a tic-tac-toe (3 x 3) grid. Players take turns rolling a standard die and placing the resulting number in one of the free squares remaining in the grid. A player can win by being the first to complete a line (horizontal, vertical or diagonal) of 3 numbers that add up to 9 (a hit). A player also wins if the other player completes a line of 3 numbers that add up to more than 9 (a bust). If neither has occurred by the time all nine squares are filled, the result is a draw. The game 9-or-bust has many variants, e.g. change the target to some other number than 9, use a larger grid, and change the numbers on the die. Our pencil and paper activity explored the effects of changing the target to 6 and to 12.

We started the session with students discussing the rules of 9-or-bust, and how they would change for 6-or-bust and 12-or-bust. The class was told that they would separate into pairs, and that each pair would play 3 games each of 9-or-bust, 6-or-bust, and 12-or-bust, using pencil and paper and a regular die. A discussion of what kind of data should be collected resulted in a decision to record, for each variant, the number of games that ended as hits, bust, draws, and first player wins. They also decided to record which variant each student thought was the most fun to play. Asked for conjectures on how they thought the results might turn out, students volunteered that there were likely to be more busts in playing 6-or-bust because "it's hard to get three numbers without going over 6".

After all games had been played, and the outcomes recorded in a table drawn on a flip chart, the class regathered to examine the results. As there were substantially more busts and fewer hits when the target was 6, and substantially more draws and almost no busts when the target was 12. The number of first and second player wins were roughly equal for the target being 6 or 9, but the first player won substantially more often in 12-or-bust. After discussing which version made a better game, we agreed to explore the reasons for differences in outcomes (hits, busts, etc.) at the next meeting. The students agreed that during the intervening week they would work on finding all the ways (roll combinations) to get hits of 6, 9, and 12, ignoring the order of the rolls of the die.

The next week's session began with making a list of all the roll combinations for getting 6, 9, and 12 that students had found. We discussed the strategies the students had used to be sure they had found all the roll combinations. We then explored the connection between the number of roll combinations for a given target, and the number of hits, busts and draws for the game based on that target. The students found the mathematical reasoning in this session very challenging. However, they seemed to accept the difficulty as a legitimate part of the research activity, and were not discouraged. When asked how they felt about the pencil and paper activity at later sessions throughout the year, they remained uniformly enthusiastic about the experience.

4. HCI for Learning Environments

We close with some thoughts on ways in which desirable interfaces and usage configurations for computer-supported collaborative learning may differ from those aimed at work environments. One is the effect of requiring two people to share a single computer, compared to providing them with individual computers. Another concerns the value of a highly intuitive interface versus one requiring more deliberate attention. A third is the effect of providing tools in the computer environment that remove the need for non-computer materials (e.g. paper, pencil, books, calculator) while at the computer. In exploring why these differences may exist, it is important to take into account some of the major elements of effective learning that we mentioned earlier: exploration, reflection, and ability to transfer the learning to other contexts. Our observations of certain interfaces and configurations as good for learning are based on our perceptions of how they stimulated, supported, or enhanced these three elements. There are obviously other important elements in learning, but these three seem particularly germane to computer-based learning.

Like many others we have observed positive benefits from having two students work together at a single computer. These include:

(a) Sharing the computer stimulated discourse about what was being done. We believe enhances learning.

(b) The discourse and the presence of the other learner made the learners remain more aware of and connected to the usual classroom environment. We believe this enhances transfer.

(c) While one learner operated the input device, the other learner frequently took that time as an opportunity for reflection and for using non-computer tools such as pencil and paper, and calculators.

(d) Learners found sharing a computer more enjoyable than playing alone.

Some of the benefits of a) and d) would in occur a groupware environment where each individual used a single computer, and there are some obvious advantages to having all learners being able to perform independent actions simultaneously. However, just as collaborative learning has advantages over individual learning, we believe that in many situations, sharing a computer has some intrinsic advantages over individual computer use or groupware environments.

In work environments, a user-interface for a given task is viewed as good if it is highly intuitive, allowing the user to perform the task with little additional cognitive load. However, our experiences in watching students play a variety of computer-based math games indicate the value of including occasions in which the player must deal with less intuitive interfaces. This is because these occasions seem important in stimulating reflection on the underlying concepts involved in the game. Of course, too much of this can quickly destroy the playability of a game.

A good example of this phenomenon occurred in Garden, an E-GEMS prototype game in which players move their pieces around in a two dimensional coordinate system. The educational objective of the game is to encourage exploration of negative numbers and coordinate systems. A turn in the game goes as follows. After rolling a die, the player is presented with a number of possible moves represented by 2-dimensional vectors. Thus a player might be offered the vector (1,0), which represents moving one unit to the right, and also the vector (-1,2), which represents a knight-move upwards and to the left. When the player chooses one of the vectors the piece is moved accordingly.

In order to help players develop their intuition of the coordinate system and how vectors correspond to moves, we designed the game so that players could tentatively select a vector, and the location that would result from the selected vector would flash. The player could then either confirm the choice, or try one of the other possible vectors. Though this interface worked reasonably well in terms of game play (students simply cycled through the vectors until they found a move they liked), we found that for the most part the players completely ignored the numerical values of the vector coordinates and the coordinate system itself. We remedied this situation by adding bonus moves in which the player selected a location in which a special effect will occur. By requiring that the player type in the coordinates of the desired location, we were able to markedly increase the attention paid to the coordinate system. Students found entering the coordinates cumbersome and difficult, but did not complain because the bonus moves were valuable and only occurred sporadically.

This question of how to stimulate reflection and awareness of the educational concepts underlying a computer game or activity, without adversely affecting usability, is deep and complex. While there are tangentially related problems in designing user interfaces for work applications (for example, the need to alert the user to possibly undesirable consequences of actions such as quitting the application without saving) it needs serious study in its own right.

We close this section on differences between computer-based work and learning environments with an observation about the usefulness of integrating helpful tools into the computing environment. Few will question the value of such tools in the work environment. Consider, for example, the inconvenience of using a word-processor without immediate access to electronic versions of common tools such as dictionaries, drawing materials, and calculators. It is thus natural for educational software designers to provide these kinds of helpful electronic accessories in their products. However, our classroom observations lead us to note that there can be benefits in encouraging students to use non-electronic tools while at the computer. In particular, making notes in their personal journals and using their own hand calculators while solving problems in the games provided effective linkage, one form of transference, between computer and non-computer activities in the classroom. Also, the simple act of switching context between the computer environment and non-computer environment seemed to stimulate reflection.

The above examples all illustrate the point that making computer use more efficient for learners can sometimes result in less effective learning.

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Exploring Cases On-line with Virtual Environments

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Abstract

A project team at the University of Virginia has combined the text and graphic format of the World Wide Web with the live interaction of a MOO (MUD, Object Oriented; where MUD stands for Multi-User Dimension) to create an on-line virtual environment for the presentation of instructional cases to Instructional Design students and professionals. The effectiveness of case methodology for the development of professional thinking has been demonstrated in a number of collaborative and competitive projects using a variety of communication technologies. The Web/MOO environment will simulate the collaborative nature of "live" interactions while taking advantage of ability of communication technologies to bring together geographically diverse individuals at minimal cost. The original project was solely MOO-based, but the decision to combine the Web and MOO environments was made after a pilot study revealed the difficulty of managing lengthy texts in a MOO environment. Future work with this project will include additional pilot studies, case competitions, and the integration of the model into case-based university courses.

1. Introduction

We have combined the graphical format of the World Wide Web with the real-time interactive environment of a MOO (MUDD Object Oriented) to develop an on-line virtual case environment that can be used to link participants from geographically or professionally disparate locations as they explore cases and develop their case responses. While this environment could be useful in practically any discipline, we have elected to focus upon Instructional Design casework. In this paper, we will provide a background on case methodology and the use of teams for collaboration and competition within learning environments. We will then describe how cases can be delivered, with a focus on our on-line case environment and our initial Instructional Design case. Finally, we will relate what we have learned about crafting an on-line case environment, closing with a description of research underway.

2. Case Methods: What Are They and Why Are They Used?

Instructional Technology (IT) majors typically spend a great deal of time learning Instructional Design theory and applying these theories to the production of instructional materials. Too often, however, these applications are not developed in response to a real instructional need. There is no client to work with and no real-world problem to explore. On the other hand, securing the involvement of real-world clients can be difficult when the Instructional Design "consultants" are students who are still learning. Case methods are particularly useful in this situation, as they provide a nearly risk-free environment in which students can explore a real problem, attempt to understand it, and then consider and generate a response.

Case-method teaching has been used extensively in the preparation of lawyers, physicians, and business people, but cases are only now beginning to be widely employed in education (Merseth, 1991). Instructional cases can be used to encourage the development of professional thinking as individuals formulate reactions to case materials. Case methodology is especially effective if students are required to identify facts and issues, to de-center and view events from different perspectives, to apply current professional knowledge and research, and to predict consequences of various courses of action (McNergney, Herbert, and Ford, 1993). In this way, the use of case methods can help students to forge important connections between the academic and the experiential, between knowledge and practice (Cooper and McNergney, 1995).

The effectiveness of case-based teaching is supported by Kleinfeld, who has demonstrated that teaching with cases can help students to understand the meaning of events, increase their ability to frame educational problems, and improve their thinking regarding alternative courses of action (Kleinfeld, 1989, 1991).

3. Cases and Team Collaboration / Competition

Most educators believe that teachers who learn to work collaboratively perform more effectively as teaching professionals. This strategy has proven effective within team competitions where it was found that a case scenario provides a rare opportunity for professional collaboration for solving real-life problems (McNergney, Herbert, and Kent, in press). Ellsworth (1994) explains that collaborative-learning students take on a more active role in the learning process. They become problem-solvers, contributors and discussants. Collaborative learning situations also increase cross-cultural awareness, increased interest, focus and synthesis (Ellsworth, 1994).

Cases have been used as the basis for competitions in which judges evaluate analyses presented by collaborative teams of student teachers from different institutions (McNergney, Herbert, and Ford, 1993). Such competitions allow participants to work collaboratively within the framework of a given system of procedures, an environment not unlike the professional workplace. Professionals maintain their status and social worth because they possess knowledge that others do not, and case competitions explicitly encourage the integration of professional knowledge and practice--knowledge of both "knowing" and "knowing how" (McNergney, Herbert, and Kent, in press).

Virtual competitions have been held over the Internet via mailing lists, e-mail, and through text and graphical presentations on the World Wide Web (WWW or Web for short). One such competition involved five teams of student teachers from three countries. Virtual competitions hold a tremendous advantage over live competitions in their cost effectiveness in regard to both time and money. Additionally, virtual competitions allow greater flexibility in bringing together a wide range of individuals and cultures for interaction in a common collaborative setting (McNergney, Herbert, and Kent, in press).

E-mail and Web technologies, however, are not real-time events. We hope to use the MOO (MUD, Object Oriented; where MUD stands for Multi-User Dimension) environment to capture the collaborative nature of a "live" competition using technology that lets us conduct real-time case competitions that allow international participation for very little expense.

4. How Are Cases Delivered?

Written cases used for classroom discussion were the first format proposed to the education community and continue to be the most popular form in use (Shulman, 1986). Emerging technologies are allowing new and innovative applications of teaching cases. Videotape can be useful in capturing actual events, or realistically simulated events, to serve as the basis for a case, and supporting text materials can guide both teachers and learners in the use of such cases in instructional settings. CD-ROM technology has been used in several instances to overcome limitations inherent in the linear format of video by making it easier for users to interact with the case and supporting instructional materials.

The Internet and telecommunication technologies have also provided new vehicles for delivering cases to learners. Listserv mailing lists (such as cases@bsuvc.bsu.edu) have been used for both discussion and formative evaluation of text cases. Because of its ability to transmit text, graphics, sound, and short movies, the World Wide Web offers substantial potential for the development and presentation of case materials.

MOOs present another interesting medium for case use. MOO-based cases are unique because of the real-time, interactive communications that can take place in the MOO environment. Bennahum (1994) describes MOOs as being very much like electronic mail (e-mail) in that computers are linked via phone lines. However, in a MOO, the communications are real-time events taking place between participants in a text-based virtual environment.

However, MOOs are much more than real-time chat. MOO environments are populated with text-based descriptions of objects that can be manipulated. For example, a virtual chair can be "sat" in by a MOO participant. A virtual letter can be read as well. As such, virtual rooms, objects and exhibits are programmed for people to interact with. Role-playing is an instructional method that allows students to experience first-hand realism of case materials as they assume the perspectives of individuals represented in a case (Ertmer, 1995). MOOs also allow individuals to assume different identities with ease and allow geographically separated individuals to collaborate in a common setting.

MOOs have been used in a growing number of academic applications. The development of writing skills has been a popular use of the MOO environment at the university level, but other applications include the use of MOOs for the discussion and sharing of research information, as a forum for social research, and in the creation of unique social and cultural environments. In several instances entire courses, ranging from freshman composition to computer programming, have been successfully conducted in MOO settings (Bennahum, 1994).

5. The On-line Instructional Design Case

The case we have employed presents an Instructional Design problem in a corporate "training and development" setting. Case documents provide biographical information on the principal players, a description of trainee responsibilities, transcripts of the initial client/design team meeting and a follow-up design team meeting, and a flow chart developed by the design team. In responding to the case, we ask participants to address the following questions, which have been patterned after the professional knowledge model developed by McNergney and Medley (1984):

- What are some of the most important issues reflected in this case?
- What do you already know that is pertinent to situations like this one?
- How would you respond? What plan of action would you suggest? and
- What do you think the outcome would be if that plan of action were implemented?

To date, we have developed and used several versions of the on-line case environment: MOO-only and MOO plus Web-based case materials. The paragraphs that follow describe our work and the outcomes we have obtained to date. (This paper was submitted to the proceedings on June 29, 1995; the results of additional inquiry will be reported at the conference.)

6. MOO-Only Case Environment: What We Learned

Our initial case environment was based solely in a MOO (IATH-MOO, Institute for Academic Technology in the Humanities, University of Virginia). Our large meeting room was designed to convene all participants. Four breakout rooms adjoined, each with a complete set of case materials. Some of the case materials were documents that could be read; others were "videotapes" (text transcripts that scrolled slowly up the screen, as if replaying an interaction) of important meetings that could be played. Once in a breakout room, a team's discussions could not be heard by participants outside of the room.

In the Spring of 1995, 11 students from a graduate course in advanced Instructional Design participated in a tryout of the case MOO. None had ever visited a MOO. The students were dispersed to computers in a single computer lab. To begin, students spent about one hour on an introductory tutorial. Printed and on-line materials led them step-by-step through the basics of MOO navigation, communication, looking at objects, and writing on notes. On completion of the tutorial, the students virtually gathered in the main case room, were divided into three teams (two teams of four students and one of three), and departed for their on-line breakout room. Four facilitators circulated among the teams, and were available for consultations during the 1.5 hour case session. At the end of the session, we physically reconvened to discuss the experience. Here's what they told us:

- The way the MOO "videotapes" functioned made them too difficult to use. While the transcript was playing back, any other activity, such as someone entering the room or team members chatting in the room, interrupted the playback on the screen.
- Reading all of the case documents on the screen was similarly difficult. Some participants resorted to printing out screen captures of the case materials.
- Holding the introductory orientation and the case exploration during the same session resulted in "overload," particularly for the less experienced computer-users. Students recommended holding two separate sessions.
- Despite the technical problems, most of the students were excited about the case and the potential of the MOO for on-line discussion.

7. Web & MOO Case Environment

As a result of our MOO-only pilot inquiry, we made some modifications to our approach to an on-line case discussion. We removed all case contents from the MOO and placed them on the WWW. The MOO environment was reconfigured to serve primarily as a discussion environment. Participants now pursue the case materials with both WWW and MOO connections open simultaneously. They are directed first to explore case documents and case questions on the Web, then to go the MOO to discuss the case and possible responses to it, and then to return to the Web to draft their individual responses and submit them. This new format has undergone several cycles of evaluation and revision to date.

8. Research Underway

During the month of July, 1995, several research activities will take place. First, another pilot will be run with two teams of graduate education students. This session will be observed, participants interviewed, and logs of the on-line discussions examined. Based on this information, the Web/MOO environment and our case methods will again be revised and improved.

The case materials will then be employed as we study how novice Instructional Designers explore a real-world design case. Participants in a summer offering of an Introduction to Instructional Design class will participate in two on-line sessions: as a group in the Web/MOO introductory activities, and as part of a smaller team of 3-4 students during the Web/MOO case session one week later. As a result of this study we hope to be able to offer a qualitative analysis of how novice designers go about addressing Instructional Design issues, as well as how they function as a team and on the Internet.

While all of our work to this point has been with students at the same geographic location and at the same level of expertise, there are several, more expansive studies planned for the near future. First, we will host a series of virtual case competitions, with teams representing Instructional Design programs from colleges and universities across the country and internationally. Second, we plan to compare the performance of novice instructional designers (still enrolled in graduate degree programs) with that of professional designers (with at least several years experience). Finally, and perhaps most importantly, we hope to employ this model as we offer case-based university courses from the University of Virginia to students across the country and world, via the Internet.

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A Collaborative Environment for Semi-Structured Medical Problem Based Learning

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Abstract

Problem Based Learning (PBL) and Cooperative Learning are both supported in a rich environment for active group learning. Groups of students are given a medical exploration environment to support learning by discovery and exploration. The environment implements a current approach to problem based learning (PBL) and extends it to support the joint reasoning and cooperation aspects in medical teams. An information system approach for a complete cooperative PBL environment, called Computer Assisted Learning and Exploration (CALE), is based upon these concepts. CALE acts as a multi-media repository for case materials and manages the structured group access to those documents and user generated information. CALE supports collaborative learning, exploration of facilitator editable medical simulated patient cases, and access to reference materials. With the case presentation shell being the same for all cases, new cases can easily be added.

Keywords: Problem Based Learning, Collaborative Learning, Exploration and Discovery Systems, Case and Knowledge Acquisition, Case Display, User Annotations, Group Support Systems, Group Tutoring Systems, Shared Information Spaces, CSCL Shells.

1. Introduction

Computers are increasingly being used in education. Often they are used to teach computer concepts per se or tutoring programs are run to teach individual students about facts in a certain domain. A number of educational software packages exist, which are often developed as specialized course-ware, that is very cost- and time-intensive to produce. Rarely do we see computers used to support a general learning approach and thus allow a generalized approach to the production of course-ware.

The area of learning in a group, working together on a problem, rather than learning facts, has received considerably less attention than the above mentioned applications. The concept of socio-cognitive processes in learning [6, 8] can add a rich dimension to the quality of information systems in the learning process. The need to provide high quality group settings in education that allow to learn domain and social skills is growing. Teachers are challenged to give adequate support in group learning situations.

The objective of this paper is to show that information systems can support a wide pedagogical spectrum of group learning. In particular, problem based learning (PBL) and cooperative learning are examined as good candidates for educational theories for which generic system support can be provided. A second objective is to show that the generation of course-ware for such a generic system can be done quickly and simply if a clear underlying model is chosen.

Section 2 introduces the general concept of problem based learning while section 3 identifies ways in which information systems can aid PBL. Section 4 examines cooperative learning and establishes a connection to PBL. Section 5 presents the design and implementation of CALE, a rich environment for active group learning. The underlying case structure and the design of new cases is described in section 6, while section 7 describes a student session with the system. Evaluations are reported in section 8.

2. Problem Based Learning: A Candidate for CSCL

Problem based learning (PBL) differs from traditional approaches to learning in that PBL centers around a problem that is presented in a context. In medical education this context is provided by documents and views, simulating a patient. Rather than learning facts by rote, students have to apply their knowledge to work on defining hypotheses about the patient's problems, supporting those hypotheses with observation, facts, and background knowledge, and eventually generating solution approaches. Facts and knowledge are thus put into context and can be turned into medical skills [11]. In a medical school PBL environment, the students typically collaborate on a case in groups of eight to twelve. Guidance in the problem based learning process is provided by medical teachers who act as learning facilitators. The facilitators help student groups stay on track, provoke lateral thinking, aid in overcoming mental blocks or dead-ends, and prevent students from pursuing improbable avenues too far [9].

Though PBL has been generally successful, the formation of student PBL groups in medicine has mostly been a matter of scarce resources, rather than a desired design parameter. Sufficient materials (X-rays, CT-scans, etc.) were not available to allow all students to work on the cases individually. Since the involvement of facilitators is extremely important, it is another constraint on the group size. Yet physicians in hospitals or private practices rarely work in an isolated manner. Doctors co-operate with other doctors, they rely on support personnel, and they interact within large organizations, such as hospitals or HMOs. By acknowledging these facts, we can turn group learning into an opportunity for learning joint reasoning skills and practicing cooperation in a medical context.

PBL has conventionally been supported by paper documents or "paper patient simulations" [2]. Recently electronic information technology has been embraced to aid in PBL (e.g., DxR, Harvard [1]). Systems have been proposed to tackle various problems posed by the PBL process, such as document handling or visualization. There are many multi-media systems that had some success at presenting a "high-fidelity" patient simulation [5]. Therefore, group size is no longer dictated by the scarcity of resources. On the contrary, information systems can directly support and foster the learning of joint cognitive skills and of social medical cooperation. Other types of systems to support learning and tutoring have been suggested. In particular intelligent tutoring systems [7, 4]. These systems will not be reviewed in detail here because they need a large knowledge base rather than focussing on tool and group aspects. In addition the focus of this paper is on learning rather than on tutoring. PBL can now be put to active use in the articulation and definition aspects of cooperative learning [10].

3. Using Information Systems for Improving PBL

One of the largest problems with current paper based PBL is its lack of cooperation support for student groups. Groups are formed because of limitations on resources. If enough facilitators and materials were available, groups would eventually consist of only a single student. This view neglects the potential of joint cognitive and learning processes as well as the actual requirements of working in medical teams rather than as a singular practitioner. With the arrival of information systems to support PBL, that argument no longer counts. Cooperative learning must be acknowledged as a goal in itself and thus actively supported.

Student generated materials are an important factor in problem based learning. While working on the case, students group their ideas, observations, and questions into categories: facts, hypotheses, and "need more information". Documenting these important indicators of progress for the next session becomes a problem in a conventional classroom setting. Records may differ, copies have to be made, and cross-references can not be established easily. Worse than that, the observations that were made about a certain document, say a blood-smear, are recorded separately from that smear. References to blots on the smear must be recreated in the next session. Cross-referencing support and the ability to pull local and coordinated central information generated by students together with the supporting original documents becomes a major need for the advance of PBL.

The use of electronic information systems can facilitate group communications, and can record the communication as the group works through the case. Annotations can be made directly on the x-rays, blood smears, etc. when a student observes a certain fact or comes up with a new hypothesis. To integrate this scattered, student-generated information, a central notebook could provide hyper-media links to the local notes and case and reference materials. Thus students would create a joint information space that records their individual and joint explorations. Asynchronous work is supported by leaving pointers, hints, and findings for group members who can build on previous discoveries.

For evaluation purposes and to give feedback to the group, the system can maintain a log of the materials accessed. Date, time, and user-id stamps can allow the evaluating facilitator to see the blind alleys tried, the integration of results by individual, or the time used by the group to finish. This record need not be a static report. Facilitators can use a play-back facility to see a time condensed development of the groups reasoning process and how it unfolded starting with the initial problem presentation, unfolding through group action.

The above review of PBL has identified PBL as a powerful method for learning skills. Yet the lack of explicit acknowledgement of group processes in the learning of skills became appearant. The next section address this lack.

4. Supporting Cooperative Group Processes

Reviewing the research literature concerning the most effective methods of teaching, one finds that success depends on the learning objective, the individual student, the teacher, and the content [8]. Juggling these factors is almost an unconquerable demand even for a master teacher; it is even more so for an information system which attempts to model each of them. The next best method can be seen in students teaching other students [8]. This observation leads us to cooperative learning. Cooperative learning is a structured form of collaborative learning.

Thus it provides a theoretical framework and an item plan for support through an information system. Hassard [6] describes the benefits of cooperative learning as follows (page viii):

> Educational practitioners such as David and Roger Johnson, Robert Slavin, and Spencer Kagan reported that cooperative learning resulted in high academic achievements; provided a vehicle for students to learn from one another; gave educators an alternative to the individual, competitive model; and was successful in improving relationships in multiethnic classrooms.

To allow more teachers to use this vehicle for more students, information systems can incorporate and enhance many of the principles of cooperative learning mentioned in the quote. Among the leading principles of cooperative learning that can be supported are:

- Cooperation: Heterogeneous small student groups work toward a common goal via positive interdependence and individual accountability.
- Active Learning: Structured assignments create discussions that lead to active learning.
- Prompt Feedback: Feedback from peers and facilitators is received immediately, continuously, and to the point.
- High Self-Expectation: Self-esteem is enhanced through an emphasis on peer tutoring and the respect for diverse results, resulting in higher expectations for ones own achievements.
- Respect for Diversity: Different learning styles are accommodated by peer teaching in the group from their own special and particular perspectives, particularly enhancing liking and respect among students from different racial or ethnic backgrounds.

5. CALE: An Environment for Cooperative Problem Based Learning

Based on the requirements outlined in the last two sections, an experimental information system to support cooperative problem based learning (C-PBL) in medical teams was designed, implemented, tested, and anecdotically evaluated. The system specifically supports improved data administration, group dynamics, group communication, and cooperative learning. The resulting implementation, called Computer Assisted Learning and Exploration Environment (CALE), is in operation[1] at the University of Pittsburgh School of Medicine for the "Integrated Case Studies and Medical Decision Making" course[2]. The system was designed to be flexible enough to support changes and paradigmatic advances in the C-PBL curriculum as it is further developed. The approach taken by CALE gives each individual student the freedom to explore and discover, while tying their individual efforts into a coordinated group learning process with a clear overall goal structure.

CALE provides students with a very rich and not overly structured medical exploration ground. The core of this discovery ground is specified by case designers, using a notation that allows concise description of salient medical facts and relationships the students are expected to discover in working through a case. Helpful probes and questions are specified that can keep the students on track so that the learning environment can be challenging without being frustrating. In addition, the case designers have feedback on how the case is actually used, so that the case can be improved for its next use. In these cases certain roles are created. One may think of the case as a network of documents that is collectively unveiled by the students, with certain parts of the network necessary to unveil other parts. Yet these parts may only be accessible to students carrying the necessary role. Thus CALE is promoting positive interdependence.

One of the goals of our system was that the students should not always need to leave the C-PBL session environment to explore reference materials and find answers to their questions. There are many resources currently online that the students can access, and many others could also be made available through the system.

The CALE system is both a "learning tool" and a "teaching tool". As such, its users fall into three categories: students, facilitators, and case designers. The goal is to link basic science aspects of medicine to the clinical environment. The students are presented with a case and can use the clinical documents that are available to analyze it.

The facilitators evaluate the work of groups by having access to the notes students have written and answers to questions, along with a chronological listing of the decisions a group has made as it works its way through a case. In addition, the facilitators assign individual students to groups and indicate the session levels which the group is allowed to explore.

Case designers create the simulated patient case by defining the exploration environment. They can attach materials to a case and specify the conditions that a group must meet in order to gain access to those materials. The goal of the design was to enable the case designers to specify a complex environment for the C-PBL session

[1] Starting April 1994.

[2] The authors wish to thank the PBL committee of the UPMC for feedback on the relation between PBL and system design. We would especially like to thank Drs. Troen, Kanter, and Williams for creating the opportunities that made CALE happen. We extend our appreciation to the software engineering students of class IS 2076 Spring 1993 for participating in designing and implementing portions of the first CALE prototype.

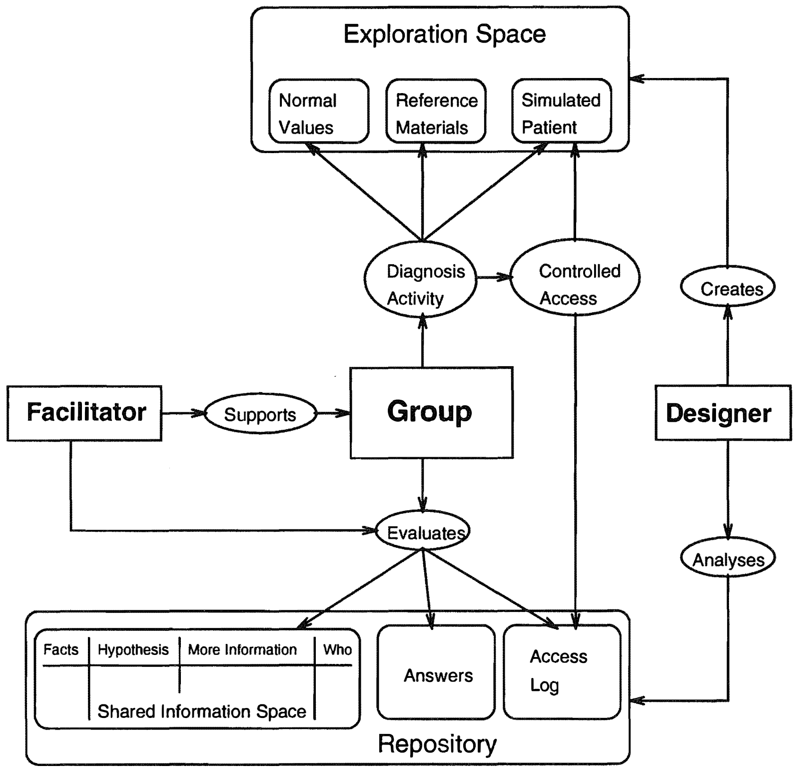

Figure 1: Major Modules of the CALE System

through the use of simple rules.

CALE is designed as an event driven system with a graphical user interface. The interface presents the user with icons, labels, and buttons representing possible choices. The system can be used with a minimum of training. There are no deep menu trees or commands that must be remembered. The flexibility of an event driven interface requires that the program handle any appropriate input at any time. In addition, the "event loop" that allows input must be programmed in such a way that the system responds quickly enough so that the user finds it responsive.

A multi-user database is used to store the structure of the case as well as a record of the individual's or group's exploration of the case such as access attempts, answers to questions, and notes. This allows several students in the same group to work on the same case on different workstations, as well as allowing students to work at different times, and have access to the group's communication. By storing the structure of the case in the database, the cases can be easily modified to emphasize different goals for exploring a case. When each material has a cost or a time attached, groups can evaluate themselves based upon these criteria, as well as on the patient outcome.

CALE is partitioned into several individual architectural modules which perform specific functions. There are three principal modules: the student interface, the facilitator interface, and the case designer interface (figure 1).

The students can access case materials, reference materials and shared and individual note taking tools from their principal control panel. This control panel is dynamic according to which categories are appropriate to the current case. Text boxes are used by students to take notes, as well as to answer questions. The central blackboard acts as the coordination center for the students. This gives structure to the discussion and allows individual students to tie observations made in an asynchronous session to the overall learning effort. CALE allows hyperlinks from the document where the observation was made to the central blackboard [13]. Thus local information and central coordination are achieved. The blackboard follows the PBL example of dividing information into three separate classes:"Observed Facts","Hypothesis", and "Need More Information". The implementation of discussion support and structuring systems has been explored in a number of of systems, such as gIBIS [3]. It has never before been applied though to medical education and cooperation. We also added another category to help the students coordinate themselves. Each entry on the blackboard, primarily those in the "need more information" category, could be turned into an action item, which in turn would be assigned to a team member with a due date. CALE keeps track of these commitments and thus allows students to structure the learning task.

In addition to the note taking ability, during the course of an interactive session a student may be prompted by the CALE system to answer a particular question attached to a material or rule. The student can respond to the question within a text window provided by CALE. Each response is saved as part of the note/text repository as textual information.

The case designer has control of the case material repository and specifies access control for the case materials. The case material repository is made up of digitized documents, including x-rays, patient charts, slides, EKG strip charts. These materials are stored with accompanying information such as date and type of medical data. The repository also contains any reference materials that are relevant to one or more cases, such as portions of textbooks, journal articles and bibliographies.

The basic function of the access control module is to provide the necessary control to allow or deny access by the student to certain case materials. When a student requests access to a case material, CALE locates the record in the materials table corresponding to the item selected. CALE then scans the request table to see if this material has been previously requested by the group or student and appends a new record to the request table noting the request for access. Then CALE checks the "question-material" table to see if the designer has entered any questions that must be posed to the student. The user is prompted with the text of the question(s) and a text editor is displayed on the screen in which the student types their answer. Finally, CALE checks for any other access constraints placed on the material item by the designer (if the material item has not yet been seen).

6. Case Design for Problem Based Learning using the CALE system.

It became apparent in the early case design work for CALE that a concise but powerful notation for specifying access restrictions and precedence was needed. Natural language and structured description techniques are quite limited in their usefulness because it is hard to keep track of all of the alternatives and possible states which may arise during the exploration of a case. In addition, it is difficult for the designer to have a sense of the overall environment that he or she is creating.

We found that many case designers think intuitively in terms of flowcharts. This approach graps the idea of semi-structured exploration of a document space rather ill. Because of the complexity of the possible solutions to a problem, facilitators think of one "via regia". The vast number of permutations that can be created by designing paths through the document space lead case designers using flowcharts to overly linear structures. If at a certain point students can either visit document 1 and then document 2, or they could equally well visit document 2 and then document 1, case designers need to use two paths to show this. The number of boxes in the flowchart keeps growing because necessarily documents appear on more than one path. Another problem with this approach is that the designers must cope with the "state explosion" by designing very linear exploration spaces, with an overly limited number of possible "solution paths". In extreme cases designers create one linear path with a small number of short cul-de-sacs branching off.

To alleviate this problem, we developed a graphic notation (figure /refnsf1) that allows case designer to specify constraints on the access to materials in a case. This notation clearly shows how open or restrictive the access is, and allows the designer to envision the complete exploration space. All solution paths are implicitly contained in this graphical notation which simply shows constraints between documents and document sets.

7. A Session with CALE

To provide an insight to the student interface, let us look at a team tackling a case. It is the first session for a new case. All of the nine students in this team are assembled, and huddle around CALE. As they log on in group mode they decide to first check the patients history. Figure 3 shows the screen entities the student group sees after this first menu selection. The patient history is shown in the window in the lower left hand corner, it consists of a video-clip of the patient and the following text: The patient under study is a 4 1/2 year old white male that has been refusing to walk for a considerable amount of time.

The control panel is located in the upper left corner. Several choices are available to the student at all times. These choices allow them to access reference materials and the blackboard, and to use a toggle switch to change between user and group mode. The rest of the choices displayed are dependent on what is available for the current simulated patient. Those are choices such as laboratory values, imaging, patient history and physical examination findings. The size of the control panel is dynamic and it can display as many or few of these patient specific categories as are appropriate.

On the right hand side of figure 3 is the notepad for local observation that relate to the patient history just seen and heard. The top half of this window allows the students to enter their observations, while the lower half contains a read only display of all of the previous notes that this student or other group members have made. In figure 3 the student has entered a comment on the notepad.

One of the students in the group suggests to follow the hypothesis that the patient is suffering cerebral problems. This is recorded under the hypothesis category in the blackboard. One of the case specific categories, "Laboratory tests" has been chosen to follow up on this hypothesis. A dynamic choice list has been displayed, listing all of the possible choices under that category. From this list a material, "CT-scan of the head" was selected triggering a question that the student must answer: "Have all necessary tests been performed?".

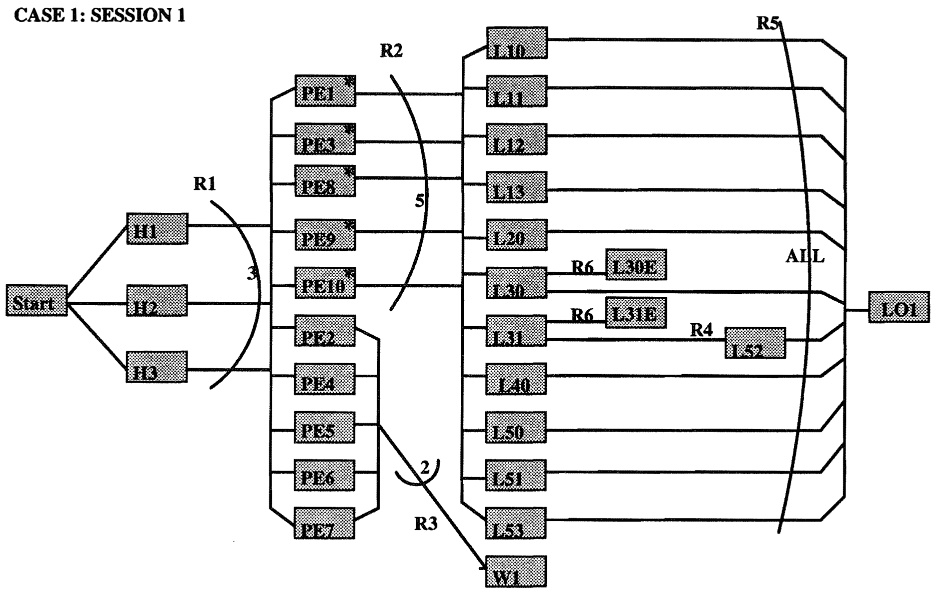

Figure 2: Case Design Graph.

A question can be linked to one or more materials, but questions are usually developed and assigned specifically to a single material. Another sample question might be: "Do you know of any third party payor who will pay for laboratory tests on a patient who was not examined?" [12] The answer to questions can later be reviewed by the group during the evaluation phase, and by the facilitator when assessing how the group did and how they can improve.

Our group answers the question just to see the message display. The hypothesis and the test are not related. Our group now starts to take a more structured approach. A number of hypothesis are generated. Each results into a number of additional information requests. These requests are recorded, like in a chauffeured meeting sessions, and student names are put behind the requests, to identify responsibilities. Thus our group has developed a first task plan. We now leave our group and come back a day later when one of team members returns to work individually in user mode.

Our student reviews the blackboard to see which information she needs to find to rule out certain hypothesis. She decides that the CT-scan should now be permissible because in the last session the group has conducted a number of test that usually precede a CT-scan. This reasoning shows to be correct and the CT-scan is presented. The student enters her observations into the margin note that pops up with the image. She thus leaves information for her team members and works on her own assignment. Her entry is linked to the central blackboard.

As she is scrutinizing the CT-scans once more, another student logs in at a branch campus. This student can only come once a week to the central university. His tasks depend on the normalcy of the CT-scan, as now cerebral problems are ruled out for the moment. Via a talk facility the two students establish contact (a later version of CALE will allow videoconferencing). They discuss their latest findings and the consequences for the probabilities of hypothesis. After this the local student logs off, while the student at the remote campus keeps working on the problem. Tomorrow the group will come back together to meet with their facilitator and review their approach to this case.

8. Evaluation and Future Research

CALE has been evaluated with two classes of medical students (ca. 160 students each) and their facilitators at the University of Pittsburgh. CALE had been introduced to the *Medical Decision Making* course. This course represents the transition from the basic science to the clinical part of the curriculum. For each group of ten students there was one facilitator and one reserved PBL room with an X-terminal that was connected to a central DEC Alpha running CALE. There were 16 such groups/rooms each semester. Each group worked on a total of thirteen cases in the course of the two months. Some cases thus ran for a week, other cases lasted less than a week.

During the two month duration of the course we closely followed the groups. In addition the students kept sending their impressions and observations about the system to the evaluators via email. A special *suggestions* button was incorporated into the system for this purpose. During the use of the system students could thus report immediately their subjective observations and impressions of the system. The second source of data collection was an elaborative debriefing session after the course with students and facilitators. This session was semi-structured

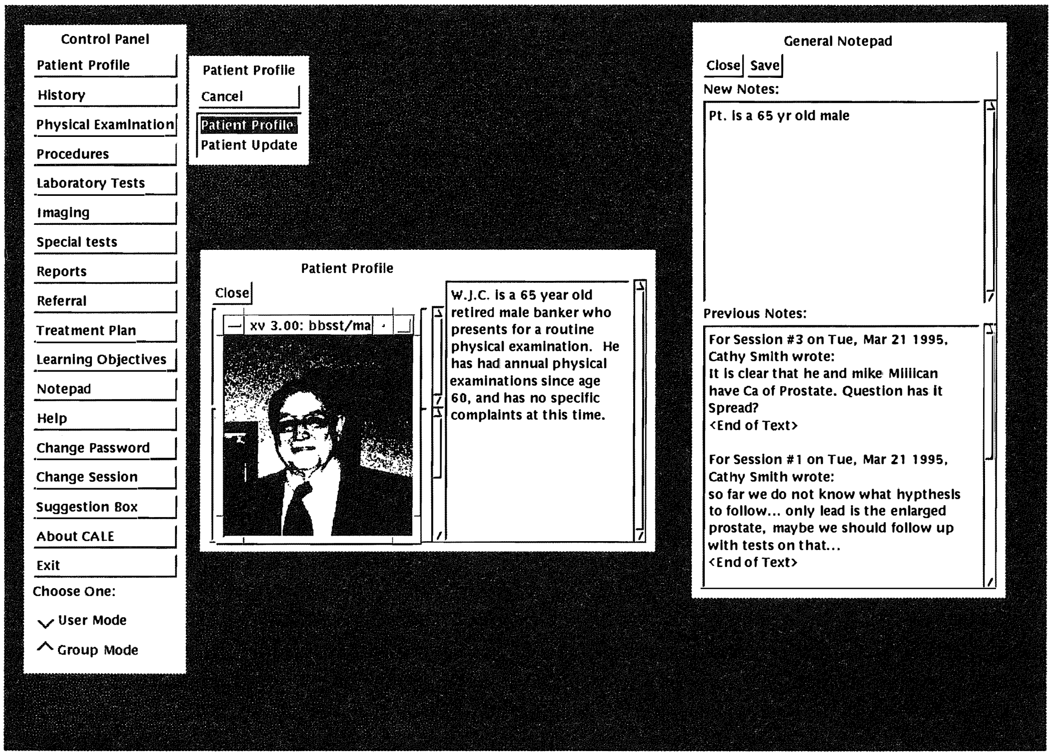

Figure 3: Opening Screen

following a topic and question list to assess subjective impressions.

Our major finding was that students enjoyed manipulating the CALE user interface and were generally excited by the opportunities offered by the system. Menus and other tools were immediately understood and used correctly. Students would try a number of solution approaches to the problem given by CALE until the system aided them in narrowing the hypothesis space. Students commented on the appropriateness of this aid. Experienced facilitators observed the students using the system and commented on the qualitative improvements over the paper based implementation.

Students noted that some of the cases were overly linear. This linearity was embodied in the number of documents that were not accessible upon request. Students commented that this repeated rejection was frustrating. During the discussion of this problem in some of the cases we discovered that the problem was not inherent in the CALE-approach but had to do with the experience of the case authors. CALE allows to build a very open and exciting environment. Yet authors do not immediately realize the potential of the system and follow the simpler linear approach of cases where one and only one action must follow the other. That of course means that most documents are not available to the students. Upon identifying this problem and working with case authors the quality of cases could be greatly improved by increasing the average branching factor in the case graph.

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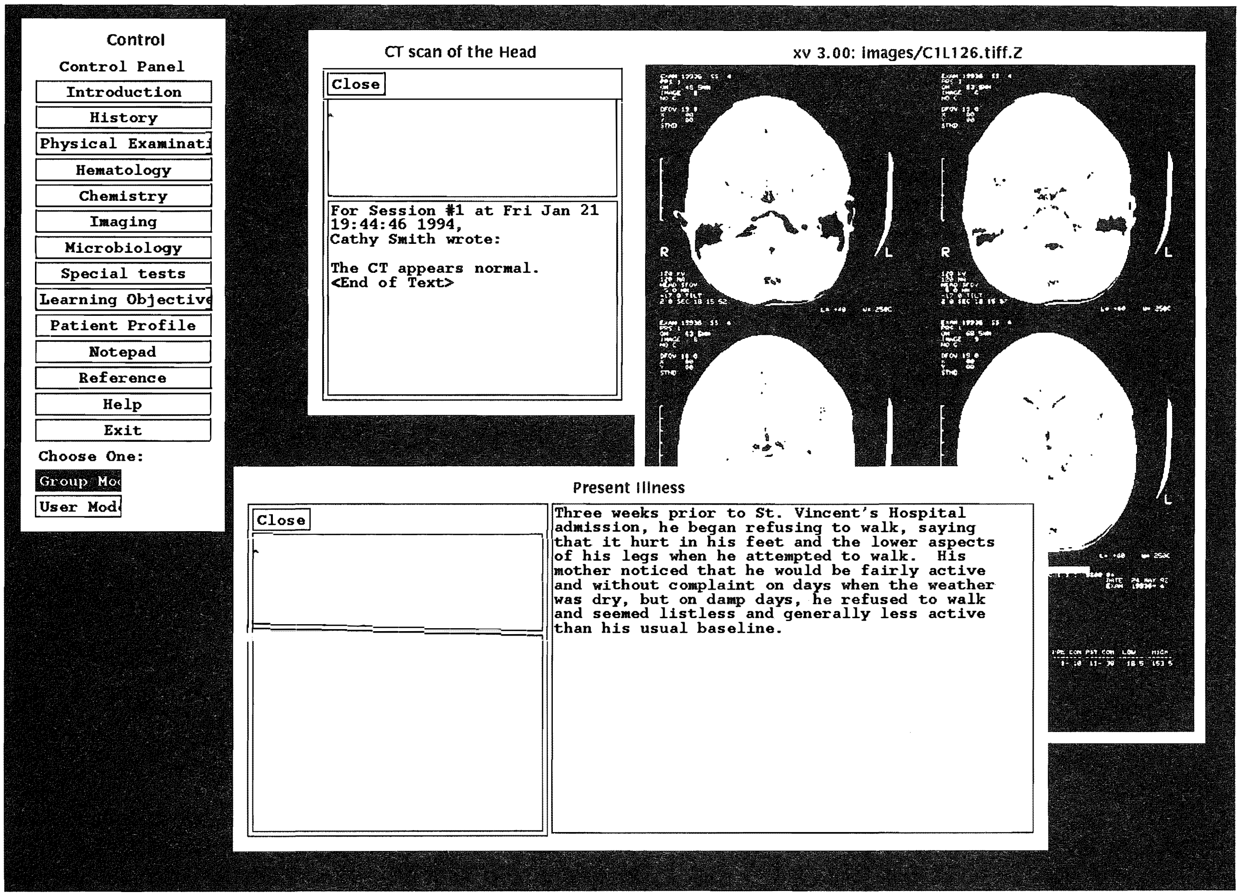

Figure 4: Sample screen from student interface

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CASENET: Creating Conditions for Conversation and Community for Teachers in the Midst of Reform

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Abstract

This paper reports on the use of CASENET (Creating Associations of Experienced and Novice Educators through Technology), a multi-year project that uses multimedia compact disc cases and high-bandwidth telecommunications to create a professional development network for teachers in the midst of systemic reform in the state of Kentucky. Initial findings indicate that the CASENET tools and resources establish conditions for mutually beneficial professional conversations that encourage participation in a professional community. Such participation has been shown to support teachers as they attempt to change practice and implement reform. Six veteran social studies teachers and six student teachers engaged in discussions of teaching strategies and garnered mutual support for the risk-taking inherent in change. The multimedia cases provided a common context for discussion and the videoconference allowed for personalized, non-threatening contacts among teachers at vastly different stages in their careers, but faced with similar challenges. A description of the CASENET tools and resources is included.

Keywords — professional development network, community and conversation building, educational reform.

1. Introduction: Professional Development and Electronic Networks

Educators have become interested in the utility of rapidly developing electronic networks to support serious, systemic reform in the nation's schools (Means, 1994). Educational reformers see opportunities for technology to support standards based educational goals (Means, 1994), to assist with innovative assessment (Sheingold and Erikson, 1994), to enhance teacher preparation (Barron and Goldman, 1994), and to scaffold learning for at-risk students (Cognition and Technology Group, 1994). However optimistic may be the promise of technology to support reform, researchers have also noted problems implementing innovative technological approaches that effectively promote systemic reform. A common problem is that technology can be used to maintain the status quo, in the service of traditional or less effective educational approaches (Newman, 1994). One factor that is crucial to the effective use of technology for reform is professional development that integrates technology (U.S. Office of Technology Assessment, 1995).

In specific instances it is now possible for teachers seeking professional development information to join on-line discussion groups, post questions to bulletin boards, and obtain text files electronically. But quantity of interaction does not necessarily imply quality (Harasim, 1990). This fact may be crucial to online professional development activity. Professional development that aims to change practice according to new teaching standards may need to engage teachers in a more intensive, structured milieu of professional community and intellectual teamwork (Gallegher & Kraut 1991) than is currently possible.

The use of cases has supported collaboration between experts and novices. Cases are an effective way to provoke thought and foster situational learning (Koschman et al, 1990), to model expert decision making in complex, ill structured domains (Spiro et al. 1988), to compare differences in novice and expert approaches (Borko et al., 1992; Borko & Livingston,

1989) and to contextualize problem solving (Cognition and Technology Group, 1992, 1991; Risko, 1992b; Risko, Vount & Towell, 1991). The CASENET project, described below, will incorporate the use of cases with the communication and collaborative potential of electronic networks for professional development purposes.

2. Background and Need for the Project

The 1990 Kentucky Education Reform Act (KERA) requires a major upgrading and installation of desktop and network technology in the 176 school districts throughout the state. The Kentucky Master Plan for Technology designates the Kentucky Education Technology System (KETS) as the integrated wide-area network that will connect school districts, the states' colleges and universities, and its government agencies. As Kentucky schools come on-line, it will be critical that viable uses of the network exist to accommodate the professional needs of teachers -- teachers who will be expected to engage in new types of teaching (e.g., non-graded primary instruction and portfolio assessment) and problem-solving activities vastly different from those they may have learned in their previous professional preparation. The case method as we have proposed here is well established as a very effective approach to strengthening the problem-solving abilities of professionals (Christensen, Garvin, & Sweet, 1993; Sykes & Byrd, 1993). We intend to take case teaching well beyond its current use through the use of CD-ROM technology and networking.

Brown and Campione (1990) have conceptualized the learning community as a network of engaged participants who collaborate in reflection, critical thinking, and change. McLaughlin & Talbert (1993) also describe the critical role of professional discourse and learning communities in transforming teaching practices. According to their findings, among the key factors crucial to building teachers' capacity for change is "participation in a professional community that discusses new teaching materials and strategies and that supports the risk-taking and struggle entailed in transforming practice." Due to the strategic role of technology in Kentucky's systemic reform, the stage has been set to use electronic networks to establish collaborative on-line professional communities to support teacher change.

3. The CASENET Project

CASENET is an on-line professional development network under development at the University of Kentucky's College of Education. CASENET has three primary components each designed to facilitate the use of authentic (true story) cases and telecommunications technology for intensive collaboration and professional development. They are:

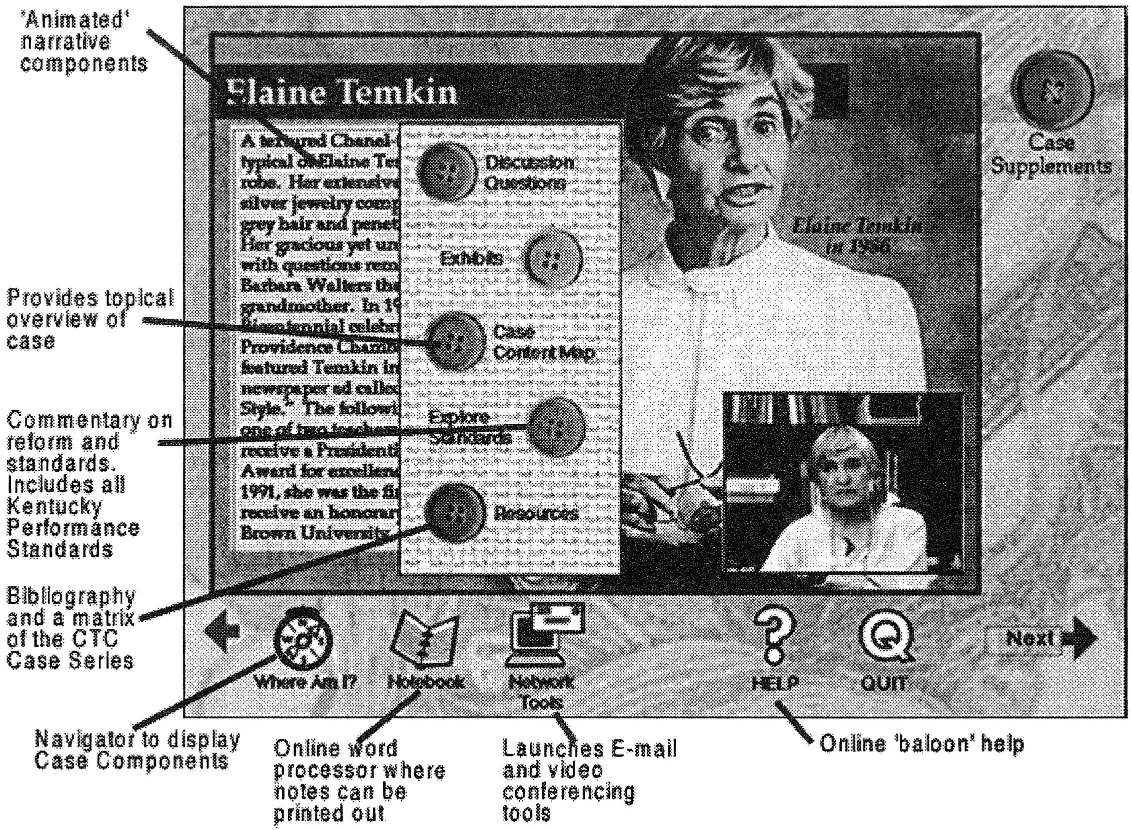
(1) True story, standards-based cases (called Common Thread Cases) in multimedia CD formats

(2) A model electronic network (with video) for standards-based professional development

(3) Research on the effectiveness of electronic case forums for ongoing professional development and collaboration between new and experienced teachers

The learning community described above is being established by integrating (1) electronic cases of accomplished teachers with (2) a technology system that allows telecommunication access to other teachers in diverse locations, and (3) focused training in the multifaceted uses of electronic cases. Using cases of successful teachers is not an new approach to professional development (Wasserman, 1993; Kagan, 1993; Kleinfeld, 1989). What is novel is a recent trend to transform hard copy cases for educators into electronic formats (Fishman & Duffy, 1992, 1993; Desberg, Colbert & Trimble, 1995). This accomplishes two important objectives: a) the creation of much richer cases that can include audio and video enhancement as well as student artifacts and b) the capability for every teacher in Kentucky to access case discussions electronically using CASENET. One of our primary goals in developing CD-ROM cases is to render highly engaging narratives of equal value to both beginning and experienced teachers. In this way, cases become the vehicle for a shared experience and subsequent conversation (Bliss & Mazur, in press). The conceptual framework and criteria for the CTC cases have been described elsewhere (Bliss & Mazur, 1995a). The interface and telecommunications tools are shown in figures 1-3 below.

To what extent can this integration of effective pedagogy (case method) and advanced technology create professional communities among veteran and novice teachers who work at considerable distance from one another? As experienced teachers in a rural Kentucky high school and student teachers at UK talked with each other about a common thread case, we documented features of CASENET. Our goal was to identify conditions for mutually beneficial professional conversations that would become the basis for participation in an on-line professional community. Would these conversations help the participants explore new teaching strategies and support the risk-taking inherent in changing practice and reform?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Bibliography and a matrix of the CTC Case Series
Where Am I?
Notebook
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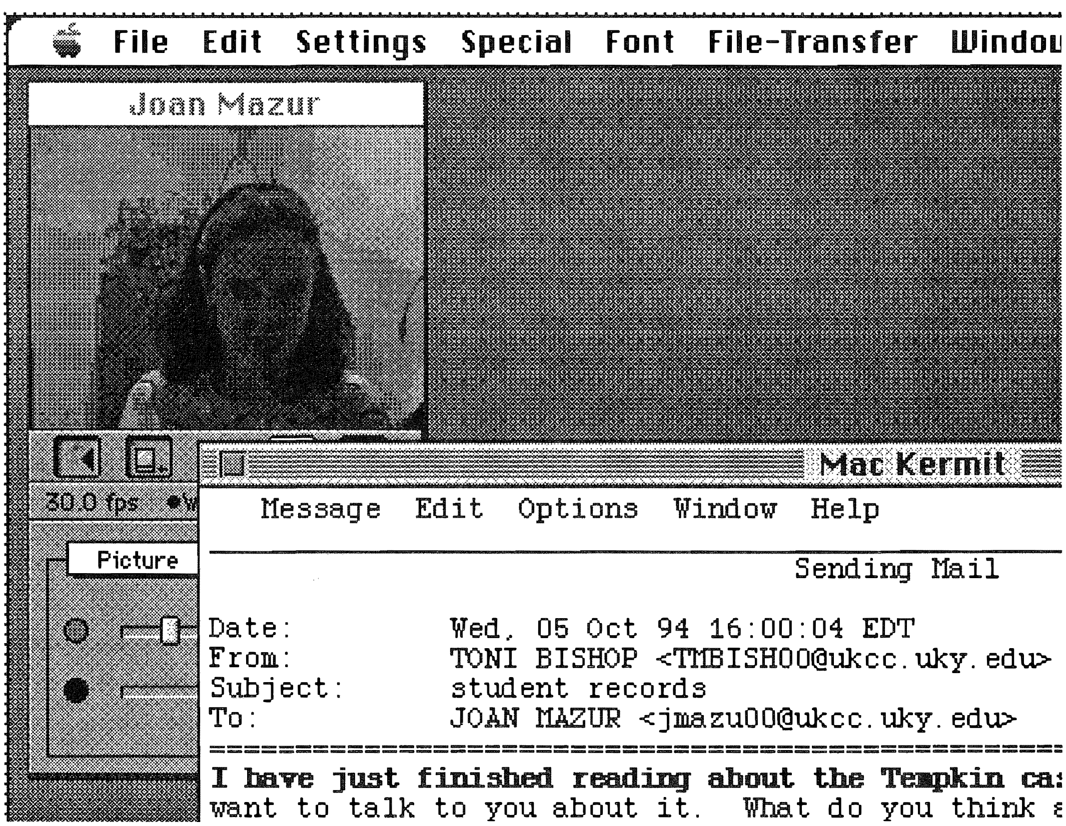
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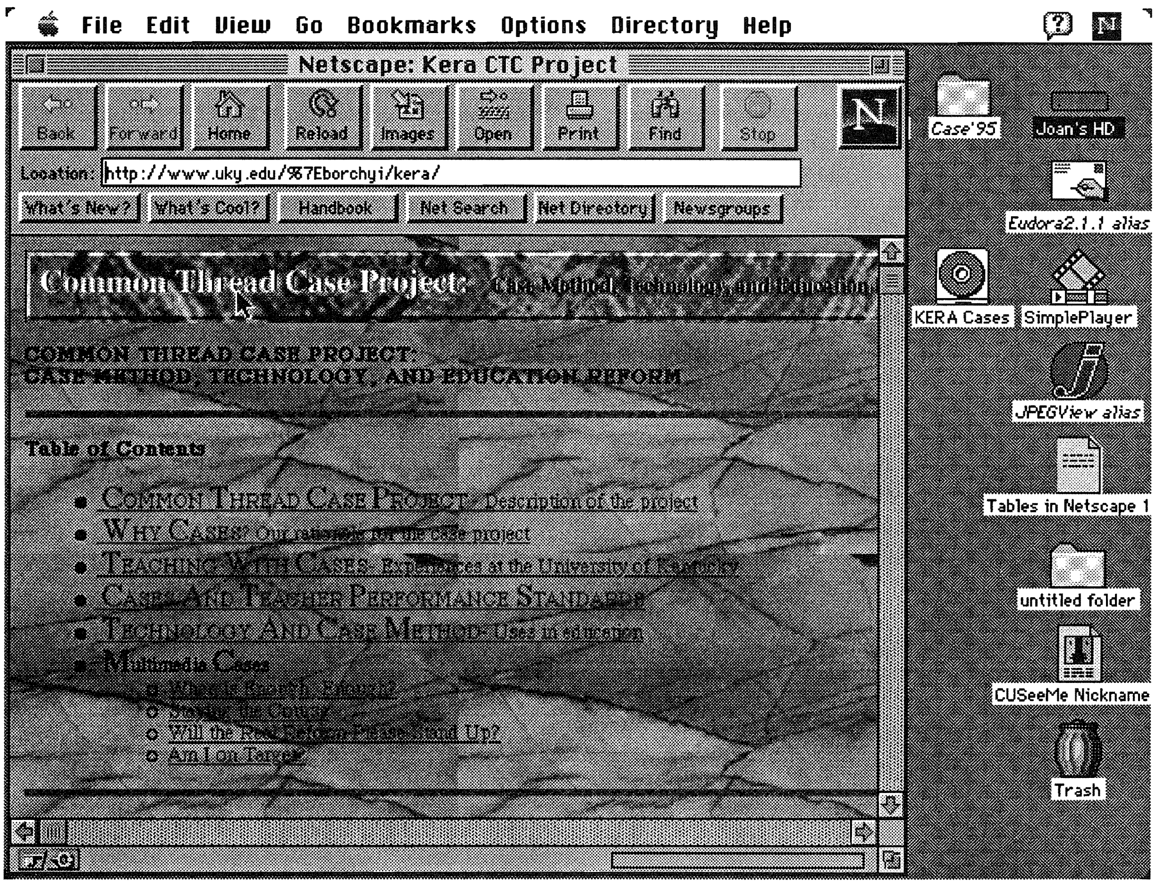

4. The CASENET Conversations

Six experienced history teachers (ranging from 18 to 29 years in the classroom) in Shelby County, Kentucky each individually studied the CD-ROM version of a case entitled "When Is Enough, Enough?" the story of award-winning high school teacher, Elaine Temkin (Bliss, in press). Mrs. Temkin teaches U.S. history thematically to provide a frame of reference for chronological events. She begins her course with a unit on the Vietnam war and uses primary source materials and cooperative learning extensively. The story focuses on the way she motivates a low achieving student, Mark, who wants to transfer to a less demanding course. After each of the six teachers had the opportunity to study the case, they met as a group for a two and a half-hour facilitated case discussion. The final activity in was a videoconference with a student teacher at the university. After the entire professional development sequence the veterans participated in a one hour focus group debriefing regarding their experiences. The researchers participated as observers. The Shelby County teachers received professional development credit for participation in the case sequence of individualized study, group discussion, and video conferencing with student teachers.

Concurrent with the Shelby County sequence, six social studies student teachers in their second semester of a Master's with Initial Certification Program at University of Kentucky (sixty-five miles from Shelby County) had also studied the When is Enough, Enough? case as part of their core curriculum. They had engaged in the same amount of case discussion as their experienced counterparts, led by the same facilitator. Each student teacher was paired with an experienced teacher for a desktop video conference consisting of a half-hour private discussion of the case.

Concurrent with the conversations, participants in both groups rated themselves as novice computer users and reported `daily to weekly' experience with basic software, compact discs, or e-mail. Compact disc technology and video teleconferencing tools were available at the university and high school site, features common to approximately 34 % of the schools in the state according to a recent survey (Mazur, in press).

Data are summarized based on the content of conversations (1) among the veteran teachers, and (2) between the novices and veterans.

4.1. The Experienced Teachers' Conversations

During the focus group, teachers commented on the multimedia aspects of the case. All six noted that the video and audio clips made Temkin and her exemplary practice real to them, and as one viewer said, "all the more admirable." Two women noted that the audio comments embellished the text and "fleshed out" Temkin's views on testing and accountability. An 18 year veteran discussed the usefulness of the case exhibits. "There were actual student writing samples, I could see the progress resulting from her teaching. This was very important to me." Another teacher noted the multimedia made him "focus more closely on the information...I didn't want to miss anything." Indeed, during the case discussion, the facilitator and observer noted the teachers' recall of detail was extensive. Although each teacher had access to a hard copy case for reference, none felt the hard copy was necessary.

The combination of individual and group work with the case was synergystic. Four teachers noted use of the CD case on the individual workstation allowed them to reflect on the teaching strategies and compare them with their own, prior to discussion. All of the veterans emphasized the importance of the focus on instructional strategies related to their discipline. The opportunity to discuss these strategies with colleagues in their own department honed their insights and challenged their thinking. One veteran who had always used a strictly chronological approach in history courses noted that he had spent two days of his recent spring break "questioning my entire 18 years of teaching....have I been wrong for this long? I've tried to put this all in perspective and consider all the sides."

Providing a forum to talk about teaching was valued. In response to a question regarding what was most beneficial about the case experience, all six alluded to the focus on pedagogy. For example, one teacher pointed to insights regarding Temkin's accountability scheme for cooperative learning. "Temkin has them come in accountable by checking homework assignments. I'm going to try that, I've never been satisfied with my accountability strategies in cooperative groups." Each discussed the pros and cons of Temkin's approach and related it to his or her own teaching context, experience, and needs. A teacher of 21 years said, "so many of us that have been in education for umpteen years have been teaching traditional, very traditional, and this experience was an opener for me to think about thematic teaching." One woman who has been teaching for 20 years summarized, "One of the things that interests me most is hearing how other teachers teach. I got into teaching because I love history...I need to be reminded of that."

At the conclusion of the focus group, the teachers reiterated the value of engaging in "flexible professional development." Four out of six teachers commented on the convenience of the CD case which could be used as part of a professional development day, after school or when time permitted. They could direct the content of their discussions and participate in an in-depth investigation of an accomplished history teacher. The self-directed, collegial case conversations affirmed their professional status, engaged their judgment, and afforded them the opportunity to discuss what interested and challenged them most: their teaching.

4.2. The Novice-Veteran Conversations

Immediately following the videoconferencing conversation, each student teacher and veteran was interviewed privately for one half-hour. They were asked, "What, if any, insights did you gain about teaching history?" Five of the six student teachers said they explored thematic teaching by discussing such topics as "what themes would you choose?" or "would the case subjects' theme of conflict and consensus really work?" The sixth student said, "it reinforced for me the importance of being really well planned for cooperative learning. I was also eager to know if starting a history course with Vietnam could in fact work." One student teacher stated, "I got some new insight into the case. Discussing the case with twenty-five other graduate students--we cover a lot of issues. but it is much different when you discuss a case like that with someone who has been in the classroom twenty years. They have different insights into what the issues are." Another teacher commented that he was heartened to know that a very experienced teacher who considered himself traditional was thinking about changes to his own practice.

The students found the video conversaton to be private, safe, and frank. Six out of six respondents commented on the benefits of talking with someone not connected with their immediate school situation.The following were characteristic of the responses: "After your first full day of teaching, wouldn't it be great to have someone experienced to talk to and not worry that you might say something wrong?"; "It's pretty risk-free being able to talk to someone who has nothing to do with your evaluation...it leads to a much richer discussion."

Conversations included discussions of new teaching approaches. Four of the six Shelby County teachers noted they had discussed the possibility of using a thematic approach with the heterogeneous groups they currently taught; these four also noted that the student teachers encouraged them to take risks and try a new approach. "It was a rare opportunity to actually talk about instructional strategy and exchange ideas like 'how do you use this theme?' I really liked this for professional development, instead of a lot of management tasks." Another stated "we discussed Vietnam and using your personal experiences to enhance the realism of the themes and topics you choose. My opinions regarding the effectiveness were confirmed by [the student teacher] and it forced me to clarify how this was useful.

The experience teachers commented on their roles as mentors. It was evident from their responses that while they believed they had something to offer the new teachers, they,too were searching for answers and trying new, somewhat risky techniques as part of the reform. One wrote this comment about the interaction, "It felt good to be seen as a mentor, I'm not sure if they saw us as true mentors-dispensing wisdom-but anyway, it gives me confidence, confidence I need to keep rethinking and changing my teaching."

5. Providing Conditions for Professional Conversations

The CASENET conversations show the case provided a common context for discussions focused on pedagogy. The participants discussed (1) the facts of the case, (2) the case teacher's instructional strategies and (3) complex pedagogical issues raised in the case. The case discussants explored pedagogical issues using insights drawn from their own experience and evidence from the case. These on-site and on-line professional conversations supported and encouraged the sharing of individual expertise and experience, a benefit of collaboration consistent with research findings of O'Malley and Scanlon (1989). Throughout the initial CASENET field test, the participants articulated individual views as well as responded to the differing comments of others, an activity that Steeples (1993) notes can lead to refinement and deeper understanding of concepts. This process of articulation and refinement may also broaden the application of underlying principles (Brown & Palinscar, 1989), a skill which will be crucial to incorporating new standards and approaches throughout a teaching career.

The CD Cases and telecommunications tools provided several conditions to support these interactions:

- ***A shared context for discussion***. Using the multimedia case as a basis for common experience, differences in the school contexts and teaching approach of each teacher could be assimilated into a discussion of the specifics of the case. This made the experience more relevant and stimulated multiple perspectives on an issue.

- ***An emphasis on pedagogy***. The true story case was believable and included specific issues and strategies related to teaching social studies. This was motivating and challenging. Teachers, it seems, want to talk about teaching and need more opportunities to do so.

- ***Flexible professional development options***. The CD cases were engaging and convenient to use as schedules permitted. This was a key benefit for teachers working around school scheduling. Also, the teachers were free to discuss topics of their own choosing either in the case discussion or during the video conference, which fostered ownership of the process. All participants were eager for more cases and contacts with other teachers.

- ***On-line contacts that were personal, safe, and proximate***. The isolation inherent in teaching is well documented. This isolation is both physical and conceptual. The video personalized the contact and the electronic link brought the Shelby County and UK sites closer to one another. The benefit of having several contacts with whom to discuss misgivings and ideas openly (without the threat of evaluation) was noted by both experienced and novice teachers.

As the participants reported, these conditions contributed to a sense of identification and involvement with their own profession, a consequence of on-line collaboration also reported by Steeples (1993). These preliminary data demonstrate how features of the CD-ROM cases and the desktop videoconferencing established conditions for mutually beneficial professional conversations. These findings are consistent with Harrington's (1993) work that suggests the potential of computer conferencing to support professional discourse. Conversations that enthuse teachers about activities such as mentoring and reflective practice are one vital component of a larning community.

6. Future Directions

It is clear from this initial investigation that more research is needed on the evolution of an electronic community of experienced and novice educators. Can participation in such a community affect teachers' ability to incorporate new types of pedagogy? For instance, what types of realistic on-line relationships (e.g. mentors, partners, case facilitators) are needed? These initial veteran-novice contacts were necessarily brief and superficial. Under what conditions do enduring on-line relationships develop and what tools are needed? In the upcoming year we plan to broaden the scope of case training and CASENET participation. Urban areas and rural Appalachian districts in cooperation with other teacher preparation programs will be included. These groups will be using the multimedia cases, desktop video conferencing, Kentucky's two-way videoconferencing system[1], as well as e-mail and the Common Thread Case Netscape home page. As we work to develop implementation models and expand participation in CASENET, we will continue to explore the role of technology in creating associations between novice and experienced educators in the midst of reform.

Acknowledgments

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A Methodology for Designing Post Graduate Professional Development Distant Learning CSCL Programmes

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Abstract

Designing post graduate professional development distant learning programmes via CSCL requires us to ensure that the technology does not become the major determinant of the programme. We have to maintain the educational values which underpin our work as adult educators, whilst exploiting the potential of the CSCL technology. This paper describes a methodology for designing such programmes which has been tried and tested on an MA course for part-time trainers and developers in the UK, using computer conferencing as the CSCL medium.

Keywords — self managed learning; learning community; professional development; computer conferencing; learning design; adult education; collaborative assessment; evaluation.

1. Introduction

In post graduate professional development programmes, the question of cooperation is central to the educational process. Adult education theory and practice has always emphasised a qualitatively different approach to learning. With CSCL, the question is how to be true to those educational values while working in an environment which is often perceived to be "technocratic" and unable to support this form of learning.

For the past six years, I have been involved in running a distant learning post graduate professional development masters degree CSCL programme, using computer conferencing systems such as Caucus and LotusNotes. The students are part-time, and are employed as trainers and developers in organisations throughout the UK. The programme is based on a philosophy which acknowledges that people learn in different ways, and has an action learning and research focus which allows participants to make choices about the management, focus and direction of their learning. Participants work within a learning community which emphasises:

- a wide choice over content and direction of learning
- the management by participants of their own learning, and cooperation with others in theirs, through processes of negotiation and discussion
- a critical perspective on learning and academic issues with strong relationships to participants professional practice
- a focus on participants own learning and development from a critical, reflective perspective combined with an understanding of relevant academic ideas and concepts
- the learning community perspective is based on participants and tutors taking collective responsibility for the design and evaluation of the programme viz constant review, modification of the design, procedures and ways of working.

The programme is based on an open syllabus. This largely non-directive approach demands constant and critical involvement by all, participants and tutors alike.

2. A Methodology for CSCL

What constitutes a useful learning design for establishing and maintaining a virtual CSCL community ? And what issues need to be addressed in designing CSCL environments ? From my own experience and research, and the experience of working closely with colleagues on the post graduate professional development MA CSCL programmes, I have found the following to be useful and important aspects of CSCL design:

- Openness in the educational process - the learning community
- Self managed learning
- A real purpose in the cooperative process
- A supportive learning environment
- Collaborative assessment of learning
- Assessment and evaluation of the ongoing learning process.

3. Openness In The Educational Process - The Learning Community

Openness in the educational process is an overarching design feature which permeates CSCL generally. Openness does not only relate to aspects of the administration of any learning event or course, where barriers to openness such as when and at what pace a person can study are relevant. Openness relates to freedom around the relationship of the learners to such things as course content and method, choice and negotiation within the course, self and peer assessment, and tutor-learner relationships. It is also to do with the learners' willingness to share ideas and be open with their intellects; to be open to new ideas and to the possibility of change.

Learners should be in a position to make decisions about their learning, and feel they have a large degree of freedom in doing so. *They also need the power to exercise their choices.*

There has to be a mechanism for achieving openness and freedom, and for the exercise of the learners' power. One which works particularly well in CSCL is the concept of the learning community, which is made up of both staff and learners who have equal rights to managing the resources of the community and the learning that takes place in it. The learning community attends to issues of climate, needs, resources, planning, action and evaluation as a whole community (Pedler 1981). This makes it quite different from traditional, staff-led courses and also from independent studies courses and flexible learning courses (Snell 1989).

The role of the tutor in all of this is crucial. The tutor has to address issues of authority and power, and has to be aware of how best to use their special experience in a community where everyone is equal, or at least where everyone has equal rights to equality. The power imbalance between learners and the tutor has to be worked on. The tutor has to become more of a "tutor-participant" and has to acknowledge that traditional forms of thinking and acting around their role have to be changed to suit the circumstances of a learning community. Notions of "there always being a right answer" or a "right way of doing something" have to be put aside. In a learning community there will always be a variety of ways of doing and thinking.

4. Self Managed Learning

Self managed learning means that each person takes primary responsibility for identifying their own learning needs. At the same time, each person is responsible for helping others identify and meet their needs and for offering themselves as a flexible resource to the community. Sources and materials for learning include each other; one's own learning practice; books and journals etc; reflection on, and "unpicking" of, learning experiences in the hear and now, and so on.

In CSCL, one aspect of self management is learning how to learn. Learning to learn is embedded in CSCL processes. It is not of the study skills variety where an expert tells learners how to learn. By playing a major role in determining their own learning and by working cooperatively with other learners and tutors, learners will have to face issues of learning how to learn within the processes of the cooperative learning group itself.

In being self-managing, learners are more likely to adopt deep approaches to learning. The responsibility of managing your own learning within the learning community quickly makes it clear to you that how you learn and why are largely up to you. Other learners and tutors in the community work with you around your concerns and interests, but you have to make the choices about how and why you are learning. This requires, and leads to, deep approaches to learning where you engage with the material, situation, issue etc in a meaningful way, and attempt to bring your own understandings to bear on it in doing so. If the community is working as a learning community (sharing, supporting, challenging, critiquing, questioning etc.), learners will constantly be faced with working at deep levels.

5. A Real Purpose In The Cooperative Process

Cooperative learning requires a real purpose in the cooperative process. This is often best achieved through a problem centred, or issue centred, approach to learning. This can take many forms. For example, each learner may define their own problem and the other group members help that person think through the problem, design ways of examining it and carry out the work around the problem. The process of working together has much in common with the cyclical nature of action learning and research. A problem or issue is posed and is diagnosed; this leads to a series of action steps being imagined which need to be taken in order to investigate the problem or issue; the action steps are carried out in whatever form has been imagined; the outcomes of this action are evaluated, and this in turn leads to a re-examination of the problem or issue in the light of the experience and knowledge gained, and a new cycle is engaged. Action learning and research are ways of dealing with real-life problems and issues. They are ways of both generating new knowledge about something while at the same time trying to change it.

At a meta-level, action learning and research inform the learners about how they are learning. The constant process of reflecting while learning, which is inherent in the action cycle if carried out thoughtfully, raises issues to do with how the learning is taking place and why, and how it could be made different : " contemporary forms of action research also aim at making change and learning a self-generating and self-maintaining process in the systems in which the action researchers work" (Elden and Chisholm 1993).

6. A Supportive Learning Environment

One important aspect of the supportive learning environment is the need to have considerable interaction between members of the groups. Learners must encourage and facilitate each others efforts. This might involve them helping each other, providing feedback, challenging each other, suggesting ways forward, acting in trusting ways and so on. Each member has to feel that they will be supported by the others. This can then produce the conditions for learners to take risks in the learning process, to try out ways of working or thinking or acting which they consider to be different to "the norm", but which might produce novel results or ideas.

A major constraint in interactions is group size. If a group of cooperative learners is too large then the possibility for frequent interaction between all members will be low. What constitutes a large group in CSCL ? A difficult question to answer. In my experience, anything greater than six or seven is large.

A supportive learning environment does not, however, suggest a lack of challenges. But a challenge in a supportive environment can be received and accepted and dealt with in a different way to a challenge in a non-supportive environment. If learners have a large degree of trust in each other, then challenges will become part of the culture of the group and will be seen as productive, if not always comfortable.

Linked to this is the need to work without fear. Where learners do not know each other and where there is little concern for being supportive and cooperative, they will be fearful of taking risks, of sharing and being open. Where there is a cloud of uncertainty in learning relationships, learners will act with caution for fear of "making fools" of themselves or "showing themselves up". Making CSCL environments safe places to work in can create stimulating, challenging and exciting learning opportunities. Learners and tutors engage in dialogue more freely and openly (McConnell 1994).

7. Collaborative Assessment

In CSCL, learners have a major role in choosing what they work on for their course assignments. They also have an important part to play in assessing their own and other learners' work. Collaborative assessment is a natural corollary of cooperative learning; it supports the cooperative learning process.

Self and peer assessment are seen as an important, integral part of the preparation for life and work generally (for example, see (Stephenson and Weil 1992),(Boyd and Cowan 1985). Although by no means widespread, there is now a wider belief in the educational and social benefits of such a process. And a recent survey looking at quantitative self-assessment studies showed that there was considerable consistency between marks assigned by teachers and students in peer and self-assessment situations (Falchikov and Boud 1989), so dispelling some of the criticism that students are not able to effectively assess themselves and each other.

Research into the relationship between assessment and learning has shown that learners will often choose how to learn, and what to learn, on the basis of their understanding of what is to be assessed, and how it will be assessed. Learners seek cues from staff about what to learn and what is likely to be examined in the course, and work instrumentally to achieve this (Miller and Parlett 1974). What students focus on in their studies, and indeed their whole view of university life, is largely governed by what they think they will be assessed on (Becker, Geer et al. 1968).

The importance of this to cooperative learning and collaborative assessment seems clear. If learners are actively involved in decisions about how to learn and what to learn and why they are learning, and are also actively involved in decisions about criteria for assessment and the process of judging their own and others work, then their relationship to their studies will be qualitatively different to those learners who are treated as recipients of teaching and who are the object of others', unilateral, assessment. Because learners in cooperative learning situations make decisions about their learning and assessment, there will be no need for them to seek cues from staff about assessment or seek to find ways of "playing" the system. They determine the system themselves, in negotiation with other learners and staff.

8. Assessment and Evaluation of the Ongoing Learning Processes

Any ongoing evaluation of the cooperative learning process must be carried out with the learners' knowledge that there is a real opportunity to change the design of the learning process.

Group processing occurs within the learning community and within each cooperative learning group. By reflecting on the way in which the group is working, the group will be in a position to change its patterns and relationships in order to better achieve what it is aiming for.

Group processing and review are mechanisms for surfacing issues in the effective running of the learning community or cooperative group. They are also ways of promoting learning about working in groups from an experiential viewpoint. Successful group strategies have to be able to survive, and new varieties have to be able to emerge (Axelrod, 1990).The tutor has to be aware of some of the techniques, models and ways of thinking about working with small groups in order to help the groups review their own processes.

But it is not sufficient just to have management skills, important as they are. What is vital is a real understanding of the purposes of evaluation in the learning community, and a real willingness, especially on the part of the tutor, to be open to change on the basis of reflection on the experiences of everyone involved. This has to be a cooperative effort. If it is seen to be addressing only the tutor's concerns and experiences then it is unlikely to succeed. And if there appears to be significant blockage on making changes then learners will feel dis-empowered.

9. Conclusion

Professional development programmes offered at a distance via CSCL have to make tremendous efforts to be true to the values associated with adult education. The technology should not be the major determinant of the programme. A methodology for designing the programme which supports adult education values is needed, and this paper is a modest contribution to that design process.

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Using Collaborative Writing and Problem-Based Learning in the College Classroom

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Abstract

This paper features two computer supported collaborative learning activities, one that has been used at the undergraduate level and one at the graduate level. The undergraduate learning activity is designed to enhance student writing while the graduate learning activity is designed to augment authentic problem-solving skills. After presenting the assignments, they are placed theoretically as constructivist teaching strategies. A brief description of outcomes of the assignments—primarily anecdotal evidence—and several research issues are discussed. Our purpose in sharing these learning activities is to foster consideration of both instructional and research issues.

Keywords — collaborative writing; collaborative conceptual mapping, problem-identification, and problem-solving; student-centered instruction.

1. Journal Publication Assignment

The undergraduate learning activity is a collaborative writing assignment—referred to as the Journal Publication Assignment—that has been used in an undergraduate educational psychology course that enrolls approximately 125 students per term. The journal publication assignment is presented in the course syllabus for Educational Psychology II, a required course taken by sophomore education majors and minors. The assignment described here has evolved in the course during the past three semesters.

Students are placed by the instructor in heterogeneous learning groups based on past performance in education courses, certification areas, computer skills, gender, and a writing sample. The learning groups are maintained throughout the semester. The assignment per se accounts for 20% of each student's grade. In addition to the journal publication assignment, students are evaluated on their self-designed demonstrations of mastery of 54 principles (which can be done individually or in groups), attendance, an individually written statement of professional commitment, and the quality of their participation. Participation includes the timeliness, completeness, and quality of feedback provided in the course of the journal publication assignment and so increases slightly the contribution of the assignment to a student's final grade beyond the 50 points mentioned below. The following is an excerpt from the most recent version of the syllabus for the educational psychology course under the heading "Journal Publication Assignment".

> Entry into the profession of teaching requires one to take responsibility for the learning of others. The journal publication assignment in Educational Psychology II will hold you accountable for and to other members of your learning group.
>
> **Group Responsibilities**
> Each learning group must meet two requirements in order for each member of the learning group to receive credit for the journal assignment.
>
> 1. The learning group, functioning as an editorial board, will be responsible for "publishing" an issue of a journal. This means soliciting manuscripts by means of a prospectus, reviewing articles, making acceptance and rejection decisions, providing feedback and editorial guidance to authors, writing editorial notes, receiving "camera ready" copy from each author, and, ultimately, producing the final version of the journal issue. The completed issue will be submitted by the group to the instructor for evaluation. The number of articles published by a board will equal the number of members in the learning group.

2. The learning group, functioning as a writing support group, will be responsible for ensuring that each member of the group is published. This responsibility entails consultation among the group members regarding ideas for articles, research, organization, draft development, and editorial advice. Each article will present a plan for a classroom project which the author intends to implement in a classroom at some future time. See the Casebook of Successful Teaching (Chapter 15) for examples of "classroom projects".

The first task for each editorial board will be to generate a journal prospectus that will include (a) the title of the journal, (b) a statement of philosophy that explains why the title was chosen and why it is useful to publish classroom projects planned by aspiring teachers, and (c) a set of guidelines for authors on the nature and format of articles, deadlines, and citation of references in publishable articles.

All boards must conform to two editorial policies. First, all names and locations used in published articles will be disguised to protect privacy. Second, the plans presented in the articles will be explicated in light of theoretical principles. The prospectus of each board will be shared with the entire class.

In response to the prospecti, each author will submit a query letter to one—and only one—of the editorial boards. Query letters provide an editorial board with a brief proposal of the article the author seeks to publish. Editorial boards will decide whether to accept or reject the proposals received and inform the authors who have submitted query letters of their decisions. Once accepted, an author will begin working with the editorial board to prepare the article for publication. If rejected, the author should expect to receive informative feedback that can be used to improve the query letter before submitting to another editorial board. Published articles must be based on readings, field work, field observations, teacher interviews, case reviews, or other research.

Assessment
The journal publication assignment is worth 50 points. Each article in a journal issue will be judged on a 25 point scale by the instructor and by a practicing teacher. The author will receive the points awarded to his or her article. Each member of the learning group will receive the average of the points awarded to each article in the journal issue submitted by the group.

Each editorial board, in addition to their journal issue, will submit their prospectus, the query letters received from authors, and documentation of acceptance and rejection decisions. This documentation will contribute to judgments about participation by learning group members and by the authors who are published by the learning group.

Timeline
The prospectus is due <date> at <time> in <location>. The journal issue is due <date> at <time> in <location>. Other dates on the timeline for this assignment will be determined by each learning group and included in each group's prospectus.
(end of excerpt)

Computer support for the journal publication assignment is primarily in the form of e-mail. Students use e-mail to submit query letters, communicate acceptance and rejection decisions, submit drafts, editorial comments, set meetings, and other intra- and inter-group communications. E-mail is also used to submit group progress reports to the instructor and to receive feedback, memos, and class agenda from the instructor. Some students use the Internet to discover journal prospecti—including graphics for journal covers, classroom project ideas, and educational research.

2. Case Problems Assignment

The graduate learning activity—referred to as the Case Problems Assignment—requires collaborative conceptual mapping, problem-identification, and problem-solving. The case problems assignment is the primary task given to students enrolled in a graduate course called "Alternative Views of Learning" which enrolls approximately 25 students per term. The course is part of a graduate program in Instructional Systems.

The learning activity begins with the development of cognitive maps. Each week, learning groups met outside of class to discuss articles they have read and to find relations among key terms generated by students from their reading. Using appropriate software in a network environment, each group is responsible for constructing a cognitive map of their combined understanding that reflects relations among terms. In doing this, each group enters definitions of terms and descriptions of links among terms. The cognitive maps are used by students to identify, define, and recommend solutions to authentic problems in the field of instructional systems design.

By mid-semester, after considerable social negotiation has resulted in fairly complete cognitve maps, each learning group begins applying its conceptual understandings to an authentic case problem. Some problems are identified by the instructor, who is aware of cases in schools, companies, banks, hospitals, and museums that present particular challenges to conventional approaches and might be amenable to analysis by this class. Other case problems are identified by the students themselves, most of whom work part or full time in some sort of training or education capacity. Once the problems have been identified, in consultation with the client, learning groups use their cognitive maps to help define the problem (and sub-problems) represented by the case and to identify relevant literature likely to be helpful in generating a solution. The goal for each learning group is to develop a set of recommendations that, if implemented, may solve the problem identified in the case. Students are also to provide a rationale for their recommendations that is grounded in the literature read during the course. The report of each group is submitted to the instructor and to the client.

Computer support for the case problems assignment includes concept mapping software used in a networked environment to support collaboration among group members as they construct cognitive maps.

E-mail is also used is to facilitate communication among groups members and with the instructor in ways similar to those described in the journal publication assignment above.

3. A Theoretical Placement of the Assignments

The assignments were designed to foster active learning through student-centered instruction (see McCown, Driscoll, & Roop, in press). Student-centered approaches define the teacher as a "guide on the side" rather than a "sage on the stage" (Johnson & Johnson, 1994). Many student-centered teaching approaches are therefore consistent with constructivist views of learning (Prawat, 1992). There are three benchmarks of constructivism as it is applied to learning (Driscoll, 1994, Marshall, 1992). One constructivist benchmark is that social negotiation is essential to learning. Both assignments clearly rely on social negotiation among learners. For example, the journal publication assignment requires each "editorial board" to produce a prospectus while the case problems assignment requires intense negotiation in the construction of the group's cognitive map.

Another benchmark is that learning is best done in "real-life" environments, complete with the ill-defined problems characteristic of every day situations. In can be argued that the journal publication assignment is not a "real-life" task for aspiring teachers. The nature of the articles generated, however, are action plans for their future classrooms and are often placed by students in their professional portfolios in anticipation of job interviews. The case problems assignment, based on extant problems in the client market served by instructional systems designers and resulting in a report to actual clients, is a highly authentic.

A third benchmark is that ideas and concepts should be learned in diverse ways. The journal publication assignment is one of several learning activities assessed in the context of the educational psychology course. The case problems assignment requires the application of a number of skills in order to complete the task.

The assignments are instances of cooperative learning in that they call for students to be teamed together to attain certain goals (Kagan, 1989; Slavin, 1991). Successful cooperative learning groups show positive interdependence among participants (Johnson & Johnson, 1994; Stevens & Slavin, 1995). Positive interdependence exists when students perceive that their individual fates are linked to the fates of others in the group (Johnson, Johnson, & Smith, 1991). The evaluation of the journal publicaiton assignment holds learners accountable for the quality of the products generated by other learners. The case problems assignment yields a jointly constructed cognitive map and a jointly produced report.

Cooperative learning techniques require teachers to place themselves in an entirely different role than do teacher-centered techniques such as lecturing. To some degree teachers share authority with students over the knowledge students gain. As students become more responsible for their own learning, teachers and students become collaborators, sharing responsibility for determining what is to be learned (Bruffee, 1993). The issue of who determines what is to be learned has been used to distinguish cooperative learning from collaborative learning (Haring-Smith, 1993, 1994a, 1994b). One approach to collaborative learning is called teaching for understanding (Talbert & McLaughlin, 1993). This approach is based on three principles: that knowledge is constructed; that the teacher is a guide, a collaborator in the construction of student knowledge; and that the classroom is a learning community that supports its members. Translated into classroom practice, these principles mean that sometimes topics are generated by students rather than presented by the teacher (Perkins, 1993). Although both assignments are fairly structured in terms of the process by which they are completed, learners have considerable latitude in selecting the substance of their products. For example, in the journal publication assignment, learners select the classroom project they will descibe in their "articles" and in the case problems assignment, learners identify their own clients and the problem they will address for that client.

4. Results and Research

Although comments of our students on course evaluations support the efficacy of the assignments, additional data will be sought. The assignments have evolved to a point where we feel confident in their form and content and are beginning to collect data to demonstrate empirically their effectiveness. What has been clear from the outset, however, is that the assignments have generated considerable effort on the part of students and a clear improvement in the quality of written products in the courses where they are usedConsider that after completing the journal publication assignment last year, a group of undergraduates have formed an editorial board, issued a prospectus and a call for papers and intend to publish the first issue of a jounral they call The Experiential Learner this fall as hard copy. Plans call for the journal to become electronic in the Spring of 1996.

We are confident that efforts to demonstrate the effectiveness of these assignments will be successful. However, one an important question to answer is, What are the effects of audience on performance? In both assignments, people other than the instructor are in receipt of the product. In the case of the journal publication assignment, practicing teachers read the journal issues. Clients read the reports generated by graduate students in the case problems assignment. Do students work harder or more effectively when the audience includes people other thn the instructor? Does audience contribute to the effectiveness authentic assessments? Does the nature of the audience interact with locus of student motivation? We look forward to answering such questions.

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Use of Collaborative Computer Simulation Activities to Facilitate Relative Motion Learning

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Abstract

Through statistical methods and analysis of protocol, we investigated how secondary students' interaction with two different sets of simulation activities could affect relative motion problem solving and mental model construction.

Though learning occurred in both treatment conditions, students who saw only animations did not perform better on a measure of relative motion understanding than students who received only numeric feedback. Interview protocol provided evidence of conceptual change fostered by interaction with the activities.

We hypothesize a framework for understanding relative motion model construction in which visual and numeric models may co-exist and be integrated into a resultant mental model.

Keywords — secondary science education, physics, collaborative learning, computer simulation, conceptual change, mental models, visualization, problem solving.

1. Introduction

Several research programs have documented students' difficulties with learning relative motion. (See [9, 10] for reviews.) Recently, research programs have investigated the use of computer simulations to assist conceptual change. (See [4, 7, 8, 14, 15] for reviews.) At SRRI, we identified several relative motion alternative conceptions and have been investigating ways that collaborative computer simulation activities can assist secondary students in learning relative motion [9, 10].

In this paper, we report results from three studies in which students' performance using collaborative computer simulation activities was examined. Statistical methods were used to explore whether interaction with collaborative computer simulation activities improved scores on a measure of relative motion understanding. Analysis of student protocols was used to explore how interaction with the activities could affect relative motion mental model construction.

2. Study Descriptions

In the studies, predict-observe-explain activities (see [8]) were designed to encourage interaction with anomalous events (see [2, 11, 13]), and to slowly build students' understanding of relative motion. Since the students had not previously studied relative motion, all diagnostic problems (pretest/posttest) and all simulation activities involved one-dimensional relative motion (i.e. all motion was left to right or right to left). In the first simulation, initial motion was in one direction to avoid overwhelming the students. Also, all screen objects were "iconic" (see [14]) to facilitate transfer.

In the studies, high school science students, working in pairs, interacted with four computer simulations presented in a predict-observe-explain format . Two treatment conditions were used — conditions DN (decontextualized numeric) and CV (contextualized visual). We had previously constructed the simulations using RelLab [6] relativity laboratory software that had been modified using ResEdit [1].

In the CV treatment, for each of the four simulations, pairs of students were given screen snapshots with labels added to the screen snapshots (see figure 1). The students were then shown an animation of an event. They were asked to predict the direction of travel of the objects relative to a new frame of reference, to supply a reason for each prediction, and to indicate their confidence in their predictions. Following their predictions, the students were shown the event from the new frame of reference. They then provided an explanation for any discrepancies between their predictions and their observations.

The DN students interacted with the same 4 simulations. However, the DN students received numeric information (a numeric speed and numeric direction), rather than animations. Their predictions concerned the speeds of objects relative to the reference frame.

The DN students' screen snapshots did not contain context labels (e.g. dog, person on bike, pyramid).

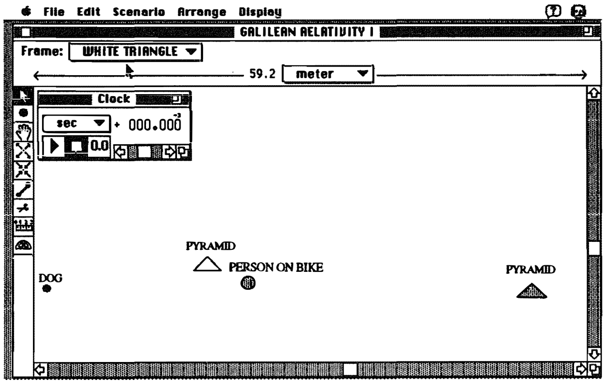


Figure 1. Screen snapshot with labels added (CV).

The authors of RelLab software, which received the 1992 EDUCOM national award for Best Natural Science Software (physics), advocate a more student-centered open-ended inquiry approach to using RelLab [7]. We constrained the interface and the activities to facilitate systematic observation of student learning processes.

3. Statistical Results

In the first study, two entire standard level physics classes taught by the same teacher in a large religiously affiliated high school were involved. One class received the CV treatment (CVstd); the other did not receive a treatment (control std). In the second study, two entire honors physics classes taught by a second teacher in the same school were compared. One class received the contextualized visual treatment (CVhon group); the other received the decontextualized numeric treatment (DNhon group). Statistical results are summarized in table 1.

Table 1: Classroom one tailed t-test results: Posttest/pretest and gain comparisons

group	n	pretest mean	posttest mean	p	mean gain	p
CVstd	19	36%	47%	<.01	11%	<.10
control std	22	45%	49%	N.S.	4%	
CVhon	19	58%	68%	<.05	10%	N.S.
DNhon	16	58%	72%	<.01	14%	

We expected the CVhon group to perform better on the measure than the DNhon group, hypothesizing that the animation combined with a recognizable context would make the simulation easier to apply to problems. We expected the CV condition to foster visualization and expected visualization to assist problem solution. However, five of nine test questions requested a numeric answer; some students may be able to calculate answers to these questions without visualization. Also, it is possible that some students were able to take numeric information provided by the DN condition and convert it to a visual representation. This skill could then be applied during problem solution. This may be particularly true for honors students who may be fluent in their use of numeric representations. Also, based on examination of students' predictions, the CV predictions were easier than the DN predictions. The CV condition may have been sufficiently easy for students that little dissonance and little learning occurred.

In the third study, 16 public secondary standard level chemistry student volunteers were involved in videotaped clinical interviews. (4 pairs received the CV treatment; 4 pairs received the DN treatment.) Below, a case study of a pair of CVchem group students provides evidence for conceptual change following participation in the collaborative predict-observe-explain activities. The case study also provides some evidence on how students may construct mental models of relative motion problems.

4. Case Study

4.1. Pretest

Protocol evidence for difficulties with relative motion pretest problems are displayed below. Student ac1 apparently ignores the effect of the motion of the reference frame on the answers for problems 7 and 9.

ac1: (question 7 — see figure 2)...if the barge is going to the left at four miles per hour, and the barge worker's walking in the opposite direction, then um, in relation to the, to the cruise ship, the um, barge worker is just staying at the same place. So it's zero miles per hour [correct answer is 10 mph]. Because um, because the barge worker is sort of evening off how far the barge has gotten away from the cruise ship.
...And I'm fairly confident in my answer.

(question 9 — see figure 2) ... the barge worker is walking towards the right, and Joe is facing the bar, barge worker. ... to keep him in his, in the telescope range, then he has to move the telescope to the right [correct answer is to the left], ... with the barge worker.

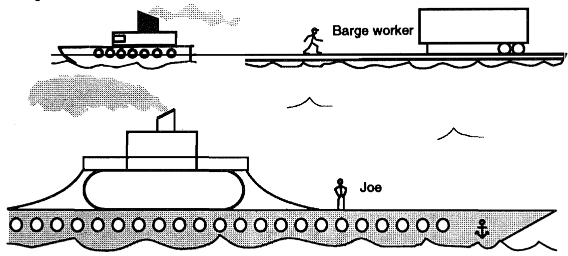
4.2. Treatment

During simulation activity 1, ac1 expresses surprise with apparently unexpected output of the computer simulation . ac2 appears to assist ac1 in understanding the simulation output, as indicated in the following protocol:

ac1: Why isn't the bike [frame of reference] moving?

ac2: If we're, I would think that if we were in like the focus of, we're on the bike, um, and you're

Joe is watching a barge from the deck of the cruise ship. The barge is being pulled by a tugboat at a speed of 4 mph, relative to the still water. A barge worker is walking toward the back of the barge at a speed of 4 mph, relative to the barge. The cruise ship is traveling at 10 mph relative to the still water.



7. What is the barge worker's speed relative to the cruise ship?
a) 6 mph b) 10 mph c) 4 mph d) 0 mph e) 8 mph
8. How confident are you in your answer? ...
9. Joe is viewing the barge worker through a telescope. To keep the barge worker in the center of his vision, which way must he move the telescope?
a) to the left b) to the right c) neither

Figure 2. Pretest/posttest questions 7-9.

looking down [points down with pen in right hand], we're going [moves right hand to the right] along with the bike so it doesn't look like it's [the bike] going.

ac1: Oh, OK. Right so then we pass pyramids, and then the dog passes us [moves right hand back and forth].

ac2: The dog passes us.

During the above interaction, both students appear to employ dynamic mental imagery (see [3, 5]), evidenced by hand motions, reports of self-projection, and the report of multiple states of the scenario. We hypothesize that such mental imagery during the treatment may assist students in visualization of relative motion problems when the computer simulation is absent (see [9] for a similar result).

4.3. Posttest

Ac1 apparently made substantial gains in her understanding of relative motion. Her posttest score on the 9 question test was 77%, compared with 11% on the pretest. For example, problems 7 and 9 revealed accurate reasoning.

ac1: (see figure 2) ... well the cruise ship is traveling to the right... ten miles per hour, and the barge worker's traveling to the right at four miles per hour, but the, um, barge is going to the left at four mile per hour. .. ...they'd [barge worker and the barge] both um, even each other off ... the barge workers' speed relative to the cruise ship would be ten miles per hour....

Similarly, her answers to several other posttest questions revealed an understanding of relative motion that had not been displayed during the pretest.

Below, she refers to the influence of the computer simulation on her solution.

ac1: I'm not sure if, if it was like the computer um, where if the um, cruise ship is ...the fix thing that ...stays still, or that is looks like it stays still, but it's really going ten miles to the, per hour to the right, then I think the uh, if the ship looked like it was staying still, then the barge worker would be going ten miles to the left, um, in respect to the ship.... on this [computer] screen or whatever, it's [the cruise ship] stayin' still...

Following a very short treatment, ac1 showed substantial gains in her ability to solve relative motion problems; she clearly and accurately transferred experiences with the collaborative simulation activities to transfer problems. It appears that the activities assisted her with visualization, providing a template for her visualization of transfer problems. (For a similar result, see [9]) Subject ac1, who made substantial gains on the posttest, was aided in her understanding of simulation 1 by ac2. It is conceivable that the cognitive effort expended by ac1 in her attempt to understand the anomalous data triggered conceptual change (see [2, 11, 13]). However, ac1's partner, ac2, did not display substantial gains, scoring 33% on both the pretest and posttest. It is plausible that this was due to insufficient experience with the collaborative simulation activities. Or, the presented activities were not at the appropriate level for her to advance her current conceptions.

5. Mental Model Construction

We hypothesize that students often construct a mental model of a relative motion problem through parallel construction of a visual model (see [15]) and a numeric model. The generation of the visual model is done by constructing a visual model of the motion of objects, relative to each medium which motion occurs in or on, and coordinating the components. (see [5] for a similar hypothesis.) In parallel with visual model construction, the student may construct a numeric model of components of the problem and combine the numeric components. The visual model and the numeric model are subject to criticism based on a student's epistemological commitments (e.g. the "true" velocity of an object is its velocity relative to the ground (see [12]). If both the visual model and the numeric model pass the epistemological commitment tests, they are combined into a resultant mental model. A clash between the visual and numeric models may cause reconstruction of either model, based on the student's confidence in the models. It is possible, however, that the student will be unconcerned with, unaware of, or unable to resolve inconsistencies between the models. (See [2].) In figure 3, the hypothesized processes of relative motion model construction are shown. Arrows reveal potential flow of mental processing.

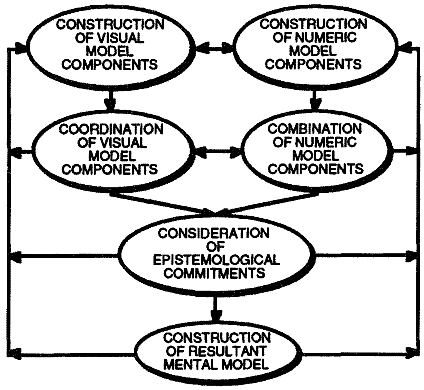


Figure 3. Relative motion model construction processes.

As an example, consider subject ac1's solution of problems 7 and 9. In her posttest protocol, she incorporated the movement of the cruise ship (relative to the ground) into her model of the problem. We hypothesize that this was done in part because the student had changed an inaccurate epistemological commitment present during the pretest, namely that the barge worker's motion is independent of the motion of the cruise ship. Additionally, it appears that experience with the collaborative computer simulation activities affected the student's visual model of the problem, as she referred to the cruise ship as equivalent to the still object on the computer screen. This analogous reasoning may indicate improved understanding of the reference frame concept, a necessary prerequisite for accurate mental imagery of the problem. We further hypothesize that critical to, and concurrently developed with her visual model, is her numeric model of the problem. Without an understanding of the numeric information present in the problem, she would be unable to produce a unique visual model of the problem; her visual and numeric models evolve in parallel, we hypothesize.

In ac1's pretest protocol , there is an inconsistency between her visual and numeric models of the problem. Her response that the barge worker was traveling 0 mph relative to the cruise ship, is inconsistent with her response that the barge worker was moving to the right relative to the cruise ship. This inconsistency is an indication that the two models (visual and numeric) are separate. It appears that consideration of the aforementioned epistemological commitment affected her construction of models.

6. Conclusions and Discussion

We provided preliminary statistical and protocol evidence for the efficacy of short, highly constrained, collaborative computer simulation activities for improving performance on a measure of relative motion understanding. Thus, collaborative computer simulation activities may be able to assist students' learning in difficult domains like relative motion. As evidenced by ac1's performance on relative motion problems which required directional answers (like question 9) and numeric answers (like question 7), it appears that simulation activities, in which only visual information is presented, can assist students in solving both directional and numeric problems.

We provided evidence for collaborative activities fostering significant progress for one student, and little or no progress for her partner. Thus, in a domain where alternative conceptions frequently are evident, varied activities, and varied strategies, may be required to assist different student's conceptual change (see [2, 4, 14]).

Acknowledgments

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Computational Support for Collaborative Learning through Generative Problem Solving

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Abstract

In this paper we present a vision of computer-supported collaborative learning through solving generative problems - problems that promote open-ended inquiry and have multiple solutions. This vision stems from a novel and evolving approach to collaborative learning that we are developing at the EduTech Institute. This approach is based on the following premises: that learning is facilitated by generative problem solving, collaborative work and use of multiple cases; that learning and skill acquisition need to be, and can be, scaffolded through software; and that a computer environment which integrates a shared and structured electronic workspace with a full variety of functionalities can effectively support all of the above. We describe this approach and the architecture of the corresponding computer environment. This environment is designed to serve three critical functions: provide a shared workspace for students, facilitate inter- and intra-group collaborative work, and make available the tools and resources that students need for problem solving and learning. The software components of the environment that have already been implemented are described. In the final section we frame ongoing and planned research and development efforts in terms of the characteristics desired of such an environment and ways of assessing its impact.

Keywords — case-based methods of instruction, educational groupware, instructional strategies and approaches.

1. Introduction

Too often, classroom instruction provides students with many bits of knowledge that they are never able to assemble and apply in productive ways, particularly outside the classroom walls. One reason for this is the focus of traditional schooling on learning isolated facts in compartmentalized disciplines. Not surprisingly, this knowledge often cannot be transferred to real-world problems. Theories of constructivism and situated cognition suggest that for learning to be useful the learner needs to be actively involved in constructing new knowledge within meaningful contexts, not merely absorbing it. Furthermore, learning is enhanced by group-oriented collaborative work, reflection and articulation. These are therefore the central premises of a multidisciplinary approach to structuring learning within the context of case-based instruction that we are developing at the EduTech Institute. This approach is called Multiple Case-Based Approach to Generative Environments for Learning (McBAGEL).

Three factors distinguish this approach: (1) The use of generative problems to promote learning. Generative problems are those that motivate open-ended inquiry, whose solutions require synthesis, which have multiple solutions, and which, therefore, promote the generation, evaluation and combination of ideas in the course of problem solving. The type of generative problems that we use are design problems. (2) The use of multiple cases provided by computer-based case libraries as knowledge sources to aid problem solving. (3) The emphasis on software-scaffolded and group-oriented collaborative work in and out of the classroom.

We are designing a computer-based learning environment that we expect students to use as a workspace for conducting work as part of this approach. The architecture of this environment and its components is the main topic of this paper. However, since the environment's role is to support collaborative learning in the context of generative problem solving, a discussion of the approach and the educational philosophy behind it precedes the description of the computer environment. Then, software components of the environment that have already been designed, implemented and used in classrooms of Georgia Tech are described. In the final section we frame ongoing and planned research and development efforts in terms of the characteristics desired of such an environment and ways of assessing its impact.

2. Educational Framework

Our approach is based on a synthesis of ideas on learning and problem solving from the fields of education, cognitive psychology and artificial intelligence. This approach is based on the following five central tenets:

(1) Learning is enhanced by problem solving. Learning is more effective when it occurs through activities associated with solving generative problems (e.g., identifying and formulating the problem, generating alternatives, evaluating, decision making, reflecting, and articulating) rather than through transmission models of instruction. Design, by its very nature, is a generative activity. Therefore, *design-oriented problems* are particularly effective for technical domains like engineering and architecture and may well provide effective anchors for math and science learning.

(2) Collaborative work is central to learning. Students are expected to solve problems and do assignments in groups. Group-oriented work, in and out of the classroom, is important both in facilitating learning and in preparing students for today's multidisciplinary team-oriented workplaces. As students work in collaborative groups, they are forced to articulate and reflect upon their thinking, leading to an appreciation of the importance of distributed cognition [14] as well as enhancing learning and subsequent transfer [3]. Collaborative work allows students to successfully tackle problems more complex than what any one group member could do alone.

(3) Access to multiple cases will facilitate flexible learning. Providing students with access to multiple cases that contain information-rich and contextualized descriptions of specific situations set within the broader context of a course can significantly impact learning and transfer. The availability and use of multiple cases during problem solving facilitates learning new knowledge, and supports the adaptation and transfer of previous solutions to the current problem [11]. It is expected that by revisiting design skills through numerous cases, flexible transfer of these skills will be supported [20]. Intelligent computer-based case libraries can provide students with not only such access but also means of flexibly navigating among cases and parts of cases.

(4) Learning and the acquisition of problem-solving skills need to be scaffolded. The experiences implementing effective problem-based learning environments teach us that solving real-world problems requires scaffolding, i.e., help from facilitators, knowledgeable experts, and the learning environment [12, 18]. The goals of scaffolding are to enable students to carry out a reasoning process or achieve a goal that they would not be able to do without help, and to facilitate learning to achieve the goal without support. The scaffolding of different skills can be provided through software, by appropriately utilizing multimedia and tools such as collaboration software, simulation and visualization programs, decision-support systems and smart case-libraries.

(5) A shared electronic workspace that seamlessly integrates a full variety of functionalities for the above will enhance learning. This workspace will tie together tools that students will use while solving problems, collaborating, and perusing multiple cases. It is also an ideal vehicle for providing adaptive software-realized scaffolding of various skills. Finally, it will encourage both synchronous and asynchronous collaborative work among students. Such an integrated yet flexible computer-based learning environment that the students use as a "professional workspace" is a central component of our approach.

We want to situate classroom learning in information-rich contexts that afford opportunities for problem formulation, exploration and discovery. Students will work on problems for extended periods of time, reflecting and articulating on both the process and the product. Case libraries will provide them with both relevant data and specific solution strategies in the domain of instruction, all within the context of complex and realistic real-world problems. The problems students have to solve and the cases that are made available to them serve as anchors for learning. Collaborative, reflective and articulative activities, aided by the tools and cases provided by the computer-based learning environment, should improve the students' knowledge, problem solving skills, and self-directed learning skills. Cases, being rich knowledge structures that explicate both conceptual and strategic knowledge, will allow the students to master concepts, principles and strategies in the course of attempting to solve problems. The collaborative nature of student activities should facilitate the construction of new knowledge since it encourages articulation and intra-group communication. Our approach is designed in particular to address the following three issues.

Cognitive Flexibility and Transfer. Consideration of a single case leads to inflexibility of the acquired knowledge and strategies [22]. Rather than having students focus on a single case, our intention is to have students revisit ideas from multiple cases both through the design problems that students work on and the design cases in the case libraries. We believe that by having students analyze multiple cases, and by having them reflect on how these cases are similar and different to the problems they are solving, more flexible knowledge should be constructed. The cognitive flexibility theory [20] supports this prediction.

Collaboration. Collaboration is a key piece of our approach. Research on collaborative learning shows that learning while solving problems in groups facilitates the learning of articulation skills, makes learning more effective for all group members, and allows students to successfully tackle problems more complex than any one group member could individually solve [3, 14, 17]. Moreover, the collaborative discussion that occurs is important for student learning because it activates prior knowledge, thus facilitating the processing of new information [2, 19]. On the other hand, Blumenfeld et al. [1] suggest that students may have more motivation to learn but make less use of learning and metacognitive strategies. In addition students may not have the skills to benefit from collaborative work. Therefore it is important to help students to collaborate well together in order to make collaborative learning work well. Aspects of our approach - the division of the student body into small groups, the complexity of the design problems that the groups will tackle, and the use of collaboration software to scaffold communication and cooperative work - are all intended to overcome these limitations and enhance the benefits of group-oriented learning.

Reflective Articulation. Two important aspects of our approach are articulation and reflection. There are several forms of reflective articulation including generating analogies [10], predicting outcomes of events or processes [21], developing questions about the learning materials [10], and self-explanations [4]. Studies suggest that reflective articulation can enhance retention, elucidate the coherence of current understanding of the problem being solved, develop self-directed learning skills, and provide a mechanism for abstracting knowledge from the content in which it was learned, thus facilitating transfer. It is very important to provide two levels of articulation - individual and group - in a collaborative learning environment. Also, it is not just articulation by itself that is important, but it is the specific kinds of articulations that engenders reflection - *reflective articulations* - that lead to enhanced understanding. The goal of reflection is to analyze and evaluate one's knowledge, learning and problem solving strategies. Several researchers have demonstrated the importance of articulation and reflection in learning. Pirolli and Recker [15] suggest that reflection on problem solutions that focuses on understanding the abstract relationships between problems is related to improved learning. Lin [13] has found that reflection on problem-solving processes leads to enhanced transfer and that technology can be used to scaffold appropriate kinds of reflections. One way that reflection can be enhanced is through the articulation of meta-cognitive knowledge and skills that typically occurs in collaborative discourse.

3. Computer Support for Collaborative Learning in McBAGEL

Figure 1 is a schematic diagram of the architecture of a software environment that we are developing to complement the McBAGEL approach in classrooms. This environment provides an external memory for keeping track of problem specifications, important facts and constraints, ideas about how to deal with the specifications, and learning requirements. The main screen provides several fields for keeping track of multiple sources of information, design alternatives, and further actions to be taken. Space is provided to record the facts and constraints that are important, to record ideas about how to deal with the specifications, and to keep track of what else needs to be learned, what information needs to be collected, and what actions need to be taken. Together, these windows allow the student to see where s/he is now, where s/he has been, and where s/he is going. This screen can be used as an individual workspace or as a shared workspace for the group. The main screen also provides access to other resources and tools that students need to solve the design problems: case libraries and other information resources; tools for simulation, visualization, decision making etc.; a tool for inter- and intra-group communication, collaboration, and multimedia document sharing; and a set of basic tools such as document processing programs, drawing/painting programs and spreadsheets.

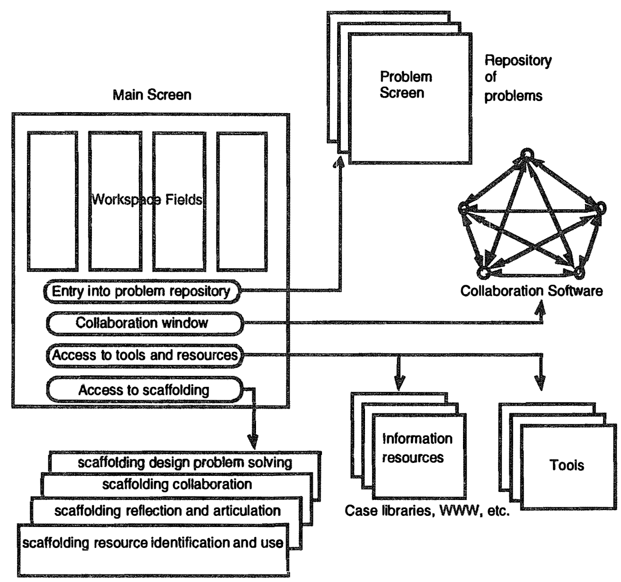

Figure 1. Software Architecture

The problem screen provides easy access to the evolving problem description. This screen begins with a minimal description of the design problem presented to the students. Details emerge as they inquire about additional information about constraints, material resources and functional issues regarding the design.

The collaboration window allows students to enter into a collaboration environment that provides much more than mere communication facilities. It will provide an ability to enter into structured discussions on different topics pertaining to the class and the problem at hand as well as to share multimedia resources with other members of the group and class. A user will be able to browse through past and ongoing discussions which are presented in a structured format to allow easy topic-based, time-based or author-based browsing, and to contribute to those discussions by constructing and sending different types of messages. This collaboration facility will be made available to not only students, but also to teachers. It will provide teachers with a means to collaborate in conducting a course and to share experiences and learn from each other. It can also be a vehicle for student assessment based on their collaborative interactions.

In addition to providing a work environment, this system makes available scaffolding to help novices with design, collaboration and reflection. Design scaffolding will vary as a function of the design stage students are working on. For example when the students are working on problem formulation, the software will provide coaching to help them understand what is involved in this stage: e.g., identifying the problem, formulating the problem, partitioning/decomposing the problem, and framing the problem. The collaboration software will provide procedural facilitation to aid in the development of collaboration skills. Reflection will be facilitated through the articulation that occurs during collaborative problem solving and learning activities.

In summary, this environment will provide means to organize and manage projects from the students' perspective (e.g., the main screen provides for explicitly listing organizational and learning issues) and the teachers' perspective (e.g., tracking student progress and keeping records of student work). In addition, we envision that the environment will be used for research purposes (e.g., archiving data such as the inter- and intra-group communications and resource sharing that took place during a course for later assessment, collecting data to be used for student/group modeling in order to devise better course- and student-specific on-line scaffolding and coaching methods, etc.). An initial prototype of this environment has been developed with Hypercard on the Macintosh platform, but it has not yet been tested in a classroom. Borrowing from the metaphor of the white board workspace of problem-based learning found in medical schools, this prototype provides an electronic workspace that is split into four regions. It also allows easy access to other tools and resources. Figures 2 and 3 show the workspace and problem screens of this prototype.

Here is a brief scenario to illustrate how we imagine the students will use this environment. Students, who will be working in small groups, enter the environment at the main window shown above, which represents their shared electronic workspace. They are provided with relevant information on the design problem they need to solve via the button "new problem". In this case, it is to design an archery stadium for the Olympics. As students are initially formulating and understanding the problem, they will be encouraged to identify data relevant to the problem from the information they have been provided with, and to articulate this by recording those in the "facts" space. Similarly, as they consider alternative solutions, they will make use of the "ideas" space. The problem-based learning methodology that this environment embodies explicitly prepares students for self-directed learning by requiring them to identify their knowledge deficiencies in the "need to learn" space and the actions they plan to take to remedy those deficiencies in the "action plan" space. Several buttons are found on the bottom of the screen that provide access to different tools that they will need to solve the problem. "Stage" is a pull-down menu which acts as a gateway to various kinds of software-realized scaffolding tailored to different stages of problem solving.

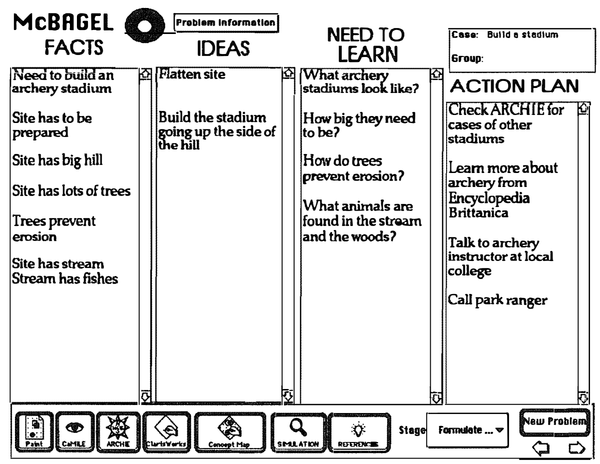

Figure 2. McBAGEL Workspace Screen

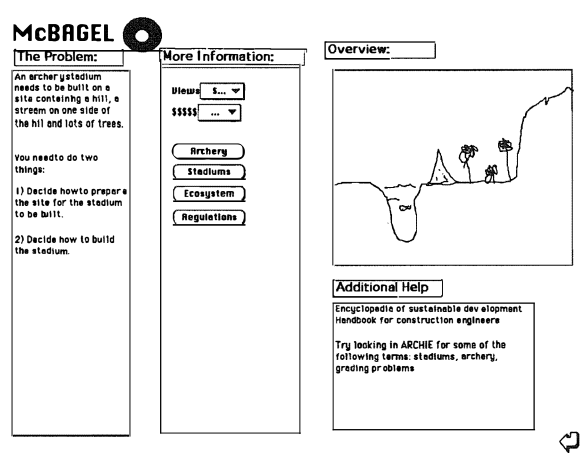

Figure 3. McBAGEL Problem Screen

While the structure of this environment is still evolving, some of its components have already been designed, implemented and individually fielded in classrooms. In the following two sections we elaborate on these implemented components and describe future directions for our research.

4. Implemented Components

• *Case Libraries:* Research on case-based reasoning [11] provides guidelines for indexing and making available resources needed while problems are being solved, especially case materials. Case libraries organize cases in ways that make it easy to access their most interesting parts, understand their implications, and recognize the range of problems needing solving and the range of solution methods available. Case studies are structured in terms of overviews, problems, stories, and responses. Each story discusses some problem that arose in designing some artifact, the way that the problem was addressed, and the outcomes that resulted. To make it easy for users to extract from stories their important points, stories are presented with illustrative graphics, and several kinds of contextual information is associated with each story. Students can examine the full artifact that some story is associated with, can see a general description of the problem the story addresses, a general description of the kind of solution it provides, and can ask to follow links to other stories that illustrate a similar problem or solution. The stories help students discover which issues they should be considering during design and help them to anticipate the results of carrying out their proposed designs. We have developed a number of case libraries in support of design problem solving.

• *Case Library Authoring Tool:* DesignMUSE [5] is a case library authoring tool that has been developed to allow easy construction of case libraries. During the 1995 Winter Quarter it was used to create a library of environmental cases for use in our sustainable technology classes. Thus, while existing case libraries act as intelligent information resources, this authoring tool will allow students to construct their own case libraries to record the design problems that they solve. Both the authoring tool and the case libraries are built on Common Lisp for Macintoshes.

• *CaMILE:* Our collaboration software CaMILE [8], based in principle on CSILE [18], integrates information-gathering tools, communication tools, and applications into a collaborative environment. CaMILE provides a discussion environment into which the full range of text, graphics, spreadsheets, video, and so on that reside locally or on the Internet can be incorporated. It is designed to meet two goals. First, it serves as a collaboration and information indexing tool. Discussions are structured and annotated with links to material anywhere across the network. Second, it serves as a design support tool. Discussions about design problems can be annotated with links to actual ongoing designs. The discussion trace can then serve as a design rationale and a case study of a design. It allows students to collaborate in learning and problem solving by providing a facility for structured inter-group and intra-group communications that are archived, and by providing a way to share multimedia documents easily among collaborators. Like CSILE, CaMILE scaffolds collaboration through procedural facilitation. While electronic mail merely allows team members to share ideas, CaMILE helps them to organize their ideas into coherent arguments, relate their ideas to one another, and use resources across the network to support their arguments. CaMILE was built with Hypercard on Macintosh computers.

• *Exploratory Simulations:* We have developed a range of exploratory simulations [16] that enable students to learn through simulated experience. Key to these simulations are tight integration with real world problems and activities, and flexible specification of simulation choices to allow for creative and sophisticated simulation problem solution. These simulations have been constructed using the Smalltalk language.

5. Future Directions

Learning from case libraries: As students are solving problems, several kinds of resources are needed to help them. Clearly, they need access to documentation, of the kind found in books and encyclopedias. But another significant but often overlooked resource is codified prior experience: e.g., cases that describe solutions to similar problems. Our approach to supporting learning from prior experience is to make on-line case libraries available from within the software environment. Cases help with understanding a problem better, suggesting solutions and parts of solutions, and evaluating proposed solutions, thereby helping a student to know where to focus his/her attention. Our research on case libraries will proceed in two directions. One is generating content: creating the kinds of cases with which to populate these libraries in order to have maximum impact on learning. The other concerns issues of information organization, presentation and navigation. How can cases be organized and presented in ways that make it easy to access their most interesting parts, understand their implications, and recognize the range of problems and the range of solutions available? While the existing case libraries provide one answer to this question (another, for example, is provided by [9]), we are currently revisiting this issue from the perspective of students, who are novice practitioners. From this perspective we believe that additional capabilities such as access to definitions of the terms used by experts, access to explanations of what experts find it appropriate to focus on, guidance in choosing what to focus on next, and allowing students to extend the libraries (or create new ones) are also required.

Supporting collaborative problem solving and learning: Support for group communication and sharing will be provided by facilitating collaborative work through the software environment. CaMILE was used during the past two quarters in a junior-level design foundations course, taught in mechanical engineering (ME 3110; Creative Decisions in Design). We have collected data on the system's usage and its effects, and are in the process of analyzing this data. A World Wide Web version, WebCaMILE, is also under development. We plan to link case libraries and WebCaMILE so that students engaged in a design activity might use WebCaMILE to discuss and exchange case-study materials. Cases provide the kinds of information that a student might point to as justification for some argument presented to others, as a potential alternative to a design decision, or as a rebuttal to someone else's design decision. Tailoring CaMILE's procedural facilitation to reflect more closely the content and nature of the problems students will be solving and investigating new ways of scaffolding collaboration are other topics of ongoing research.

Software-realized scaffolding: Of particular importance in making this integrated software environment work for students is providing software-realized scaffolding to support student use of the environment for learning. We have identified several specific areas in which we can provide facilitation.

• Scaffolding collaborative design and problem-solving: Our environment will provide scaffolding for design and problem-solving using several techniques:

– By structuring the kinds of entries which can be made in a group discussion, e.g., new theories or ideas, alternatives, comments, rebuttals, and questions. When a student chooses one of these kinds of entries, an editor opens for their comments and a prompting window opens with suggestions for useful entries to make, e.g., for a rebuttal, suggestions might include "The strengths of this idea are..." and "But the key weakness is...". This scaffolding guides the discussion in useful directions defining the kinds of entries to be made, asking students to choose one before entering an item into the discussion, and suggesting appropriate things to say.

– By providing agents to actively review student work and suggest better ways to design and solve problems. For example, agents may identify where connections might be made between efforts, where additional resources exist that might aid an effort, and where efforts may be going astray [6].

– By providing menus of glossaries of relevant vocabulary and their definitions.

– By providing means of visualization and making explicit the design process.

• Scaffolding reflection and learning: We want to support two kinds of reflection in the environment because we believe that reflection can significantly facilitate learning.

– Reflection-in-action: The students' articulations in the discussion, the declaration of item type, and the linking of cases to discussion are all forms of reflection-in-action. These are kinds of reflection which are integral to the design process and which support both the execution of a good design process and the learning about that process. Reflection-in-action helps to make strategies explicit and learnable, develops an expanded repertoire of strategies, and improves student understanding and control of the design process.

– Reflection-as-summary: Student summarization at the end of a design process is an important learning activity for students and an important resource for future groups of students. Our plan is for students to summarize their group design projects such that summaries from one class become cases in the library for the next class. Thus, students summarize not just for their own benefit but to help a future audience.

• Scaffolding resource identification and use: Case libraries support student exploration by providing multiple indices into cases. Students might begin by looking at one case of interest and then explore related cases by a number of different dimensions, or begin by browsing all cases related to a problem. Students can gain perspective on what problems they are facing, what the parameters of the problems are, and how these parameters are explored in the cases in the library from case overviews. We want case libraries to provide support for all these kinds of searching and browsing, but coupled with support that helps in applying the found information to the task at hand (e.g., linking cases that highlight an important alternative solution to the discussion on that alternative). In addition, we envision the use of visualization tools to aid in resource identification and use.

Integration: As many of the critical components of the software environment are being implemented and used in classrooms, the most significant task ahead of us is integrating the different pieces into a single environment. This integrated environment supporting the McBAGEL approach has to play several roles: facilitation of design problem solving and its constituent components, facilitation of learning, access to resources, and access to teachers and fellow learners. The software environment has to serve as both an electronic workspace and a learning environment providing help with a variety of intellectual activities as students collaborate on design projects. We see a need for this environment to promote reflection and summarization as well. Software-guided reflection is particularly important in facilitating skill transfer between different problem domains. The construction of such an environment on Macintosh computers is currently underway.

Assessment: The next step, slated to begin in Fall 1995, is to use and assess both the approach and the concomitant software environment in a series of design courses at Georgia Tech. We will use assessments to determine what kind of learning has occurred and how well students apply what they have learned. The goals of learning involve not merely acquiring a set of static facts to be recalled on a test but rather involve constructing a coherent understanding of a domain that can be flexibly transferred to new situations. The extent to which learning can be used in new situations (i.e., transfer) allows assessment of how flexibly the students have learned the content and are able to apply it to complex problems. Students' learning will be evaluated on mastery, near-transfer, and far-transfer problem-solving. Cognitive research suggests that because problem-based instruction is geared towards complex curricular objectives, assessments need to include open-ended questions in which students explain what approaches they have to a problem and its solution [7]. A variety of methods will be used to collect this data including interviews and paper-and-pencil short answer tests. This allows measurement of the products and processes of the students' learning. Some authentic performance assessments will also be devised. Students' presentations will be assessed to examine how they define the problems and justify their solutions as well as the quality of their solutions. Because transfer is not an all-or-none phenomenon, different types of transfer will be assessed and measures will be developed that assess this. We will use measures of knowledge, skills, planning, and qualitative understanding as students are asked to justify their solutions. This will assess the flexibility of the knowledge that the students construct. For example, because of the emphasis on problem solving, we would expect increased integration of the content they are learning into their problem-solving on transfer problems. Because students are using the collaborative environment and gaining experience and feedback in articulating their plans for problem-solving, we expect improvement in the students' planning skills as well.

6. Conclusions

Collaborative learning environments have the potential for helping students to construct usable knowledge and to learn strategies that prepare them for a lifetime of learning. To afford generative learning, such environments need to contain rich sources of information. In addition, opportunities for student collaboration, articulation and reflection must be provided to help students think deeply about the problems they are working on and to learn to go beyond the given problems. The McBAGEL approach is designed to meet these requirements. Providing computational support to this approach requires the design of a software architecture that integrates multiple tools and information resources with a structured electronic workspace. This paper describes our efforts on developing the theoretical and practical aspects of such an architecture. The focus of our current research is on refining and testing the components further, and on fully implementing the integrated environment. Future research will focus on deploying it in classrooms and conducting assessments of its impact on student learning.

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Learning to Weave Collaborative Hypermedia Into Classroom Practice

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Abstract

This paper presents a quantitative case study of the initial adoption of the Collaboratory Notebook, a collaborative hypermedia tool for inquiry learning, by a high school science teacher and his students. We document two distinct patterns of work resulting from the teachers' design of classroom activities and assessments. On the basis of these experiences we argue for the importance of clarifying and prioritizing pedagogical objectives for collaborative hypermedia before designing activities and assessments, so as to reduce the opportunity for resource conflicts in the classroom.

Keywords — collaborative hypermedia, activity design, classroom practice.

1. The Collaboratory Notebook

An important goal for designers of collaborative hypermedia for educational settings is to be able to advise teachers on how to couple these applications with their own curricular activities in order to achieve pedagogical objectives. Just as an experienced teacher is able to anticipate the classroom activity structures that will result from assigning a traditional research paper with a specific methodology and set of evaluation criteria, a teacher who designs activities which include the use of collaborative hypermedia should be able to anticipate the influences that the medium and the means used to evaluate work in it will have on the students' activities and their results. If this is not the case, the technology will fail because it is too difficult for teachers to plan around.

The Collaboratory Notebook is a collaborative hypermedia system which was designed and built as part of the CoVis Project at Northwestern University to serve the project's objective of applying networking and computing technologies to support a project-based approach to science teaching and learning [1]. It provides a shared, multimedia database for use in distributed, multimedia learning environments [2], particularly ones with a focus on open-ended inquiry. The software is intended to provide students with a structured environment for conducting inquiry, both with one another within the confines of a single classroom and with fellow students and scientist mentors located at a distance. Its internal system of page labels and links is intended to guide students through a series of sensible investigative steps, allowing commentary by collaborators and the cultivation of new questions along the way. (For a detailed description of the Collaboratory Notebook software see [3, 4].)

As a step toward the goal of developing a set of expectations for teachers about particular uses of the Collaboratory Notebook, we conducted a qualitative and quantitative analysis of the early use of the software by a 9th-grade Earth Science teacher and his classes during his first year of participation in the CoVis project. The objective of this analysis was to understand the interactions among the following three critical elements: the work performed by students in the Collaboratory Notebook, the design of the software itself, and the design of the surrounding activities and assessments by the teacher.

2. The Setting and Activities

The two classes involved in the study were honors freshman Earth Science classes with 19 and 20 students each, taught at a suburban Chicago high school. The students came from mostly middle- and upper-middle-class households in which about half of the students' mothers or fathers have graduate degrees. Their teacher is a second-year teacher, new to the school this year, with a previous career as an applied scientist.

The classroom in which the study took place is unique in the school. As a result of the school's participation in CoVis, this classroom has been outfitted with six Macintosh Quadra computers which have direct, 128Kbs access to the Internet. A significant portion of the activity in this classroom is project-based, and twice a week the class period is doubled in length to provide students with more time to work on projects.

Clearly, this is a resource-rich classroom, in many senses of that term. However, as our analysis shows, it still provides significant constraints on the use of a collaborative hypermedia tool like the Collaboratory Notebook and the activities to which it can contribute.

2.1. The Climate Project

The first of the activities we will discuss here was a long-term, individual research project for which each student selected a topic related to weather, climate or oceans. We will refer to this project as the "climate" project. Students were required by their teacher to produce two main products in this project: a project proposal and a standard research paper between 5 and 10 pages in length.

Students created their project proposals over a period of two weeks using the Collaboratory Notebook. Each project proposal was required to contain the following elements:

- a research *question*
- an initial *conjecture* about an answer to this research question
- a *plan* for confirming or disconfirming the conjecture
- a list of references to background research
- a hypothesis formulated on the basis of the initial conjecture and the completed background research

The teacher reviewed the students' electronic notebooks regularly as the students produced these elements and provided frequent written feedback in the form of commentary attached to their electronic notebook pages. This commentary was usually about the formulation of project *questions* and *plans*, the completeness of the work with respect to assessment requirements, or the appropriateness of the way that the students were using the Collaboratory Notebook's page labels and links.

An analysis of the notebooks created during this project (Table 1) reveals that both the students and their teacher conducted a significant amount of work in the Collaboratory Notebook, and that they found use for most of the inquiry-oriented page labels available in its palette. However, some of the labels, notably *evidence for* and *evidence against*, were rarely used (see Figure 1), and *commentary* was almost exclusively used by the teacher.

Table 1. The total number of pages and words in a sample of 39 student notebooks.

	Mean	Min.	Max.	Std. Deviation
Student pages	9.33	3.00	23.0	4.17
Teacher pages	3.31	0.00	8.00	1.95
Total Words	609	156	1666	352
Words/ page	48.7	17.1	119	25.9
# page labels used	5.64	2.00	8.00	0.973

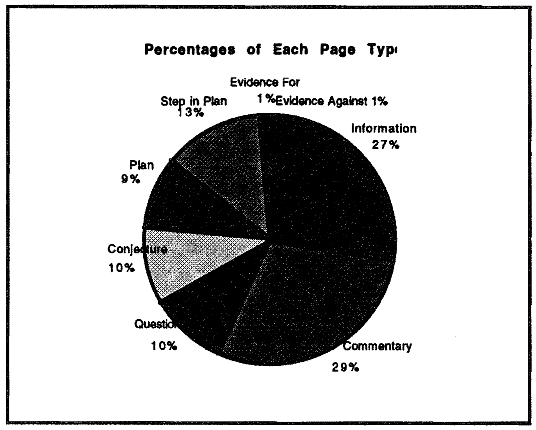

Figure 1. Percentages of pages written in the climate project (student *and* teacher) which were given each page label.

2.2 The Geotime Project

The second activity planned by the teacher, which we will refer to as the "geotime project", differed from the climate project in three important ways. First, this activity was conducted by project teams rather than individual students. The teacher made the decision for this to be a group project largely because he found it time-consuming to regularly read and comment on an electronic notebook for every student during the climate project. Second, students had less flexibility with respect to their project topics than they had been given in the first project cycle. Rather than being free to explore any question they found interesting within a broad topic area, each student group was required to master materials about a specific period of geologic time, mostly using traditional resources found in the library.

Last of all, and significant for our later discussion, the proposal format for the first activity cycle that was outlined above was not made a requirement by the teacher. Since the research project seemed well circumscribed he felt this formality was not necessary, although he hoped that students would continue to follow his proposal format regardless of his grading criteria. In place of a formal proposal, students were asked to write narrative "journal" entries in the Collaboratory Notebook, reporting how their groups had spent the project time allotted to them in class, how they had divided their labor and so on. Thus in this project, the Collaboratory Notebook was used more as a diary of activity than as a log of or support for discrete milestones associated with scientific inquiry.

3. A Comparison Across Projects

As mentioned earlier, the object of this analysis was to begin to address the question of how classroom activity, as designed by the teacher and realized in a particular resource environment, shapes Collaboratory Notebook use by students. Here we will use the size of notebooks and notebook pages and the use of page labels as primary indicators of software use in each project.

3.1 Size of notebooks and pages

We began by comparing the size of students' electronic notebooks, as measured by the total number of notebook pages, and students' verbosity in these pages (bytes per page) across projects. We also compared students' verbosity in notebook pages given each of the 8 available labels. Some of our results are presented in Figure 2.

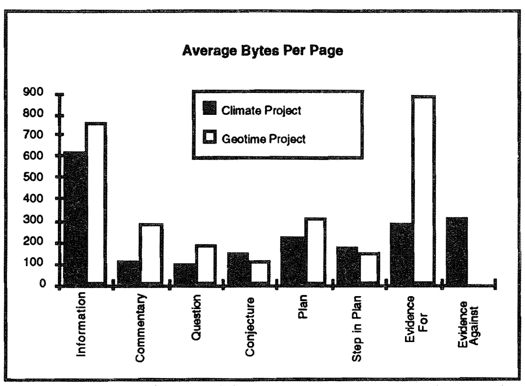

Figure 2. Comparison of bytes per page type by project and page type.

On average, students working on the climate project produced roughly the same number of notebook pages as students working on the geotime project (12.83 vs. 11.83, $F(1,329) < 1$). However, as Figure 2 shows, pages from the geotime notebooks were, on average, longer than those from climate notebooks (382.64 vs. 214.83, $F(1, 329) = 3.87$, $p < 0001$). There are at least two possible explanations for this. The pages of the geotime notebooks may have been longer because the teacher requested collaborative work and as a result, more students contributed to each page. However, an equally strong hypothesis is that they may have been longer simply because narrative journalling was easier for students to do than the more formal proposals, allowing them to produce more text in the same period of time. There is corroborating evidence for this second hypothesis in the students' use of page labels.

3.2. Use of page labels

Because the geotime project required group work, we might have expected the project notebooks created by students in that project to make richer use of the Collaboratory Notebook's palette of page labels. For example, we might have expected to see students posing *questions* to one another, offering *commentary* on one anothers' work, or contributing *evidence* to confirm or disconfirm one anothers' *conjectures* in the team notebook. However, we did not find this. In fact, the collaboratively-authored notebooks actually contained a *smaller* variety of page types overall. Approximately 2 fewer types of page labels were used per notebook in the geotime project than in the climate project ($t(47)=-5.038$, $p<0001$). How could this be?

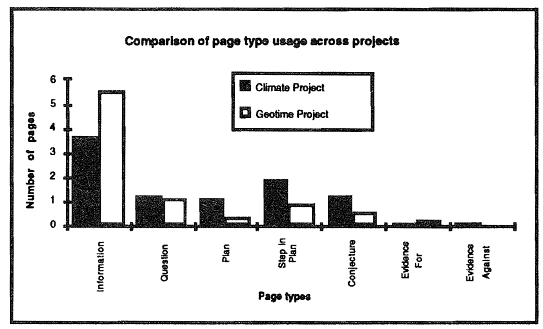

Figure 3. Comparison of page label usage across projects.

In discussions with the teacher, it became evident that the requirement of maintaining narrative journals of project activity in the Collaboratory Notebook was creating a resource conflict with the process of project refinement that the teacher had also hoped would be part of the students' work. Because there were a limited number of computers and limited time available for students to use the Collaboratory Notebook, students were forced to make a choice between spending their time creating journal entries or on using the Collaboratory Notebook to draft *questions, conjectures, and plans* to develop their proposal. The teacher, who was experimenting with journalling as a means to develop the students' reflectiveness, placed a strong emphasis on this activity, and as a result, students chose to spend their time on journal entries. These entries, most of which were labeled as *information* pages, contributed to the significant increase in the use of the *information* page label from the climate project to the geotime project (3.6 vs. 5.5, $t(47) = 2.57$, $p < .01$), and a significant decrease in *plan* pages (1.05 vs. 0.33, $t(47)=5.08$, $p<.0001$) and *conjecture* pages (1.24 vs. 0.058, $t(47)=2.21$, $p<.05$). See Figure 3 for more detail.

One may note that there are approximately equal numbers of *question, evidence for, evidence against*, and *commentary* pages in both sets of notebooks. We believe that the number of questions remained similar between both projects because posing questions is the first step in students' investigations and may have been completed before the resource conflict reached a critical level. Very few *evidence for* or *evidence against* pages were created by students in either project, consistent with the use of the Collaboratory Notebook mostly during the project planning phase rather than the later evidence-gathering phase of the projects. There was also no significant difference in the number of *commentary* pages written between projects. This constancy in the number of *commentary* pages written can be confidently attributed to the teacher's diligence in providing frequent feedback to his students in the form of *commentary* pages.

4. Conclusions

Although we hope to scaffold students' investigative thoughts and actions with the Collaboratory Notebook's page labels and links, we recognize that teachers are the ultimate designers of classroom activity. We have seen from this case study of teachers' and students' initial adoption of the software that the teacher's activity design shapes the of use collaborative hypermedia just as it shapes how students use many other classroom tools. In the classroom, students' time is definitely not their own.

In this study, the teacher crafted two relatively different projects, and his project assignments led, sometimes unintentionally, to very different patterns of Collaboratory Notebook use. When the teacher created a project whose primary written component was proposal writing, students used the Collaboratory Notebooks' page labels and links with some sophistication. When, subsequently, the same students were asked to write narrative journals with the software, they experienced a resource conflict between two types of composition for which the Collaboratory Notebook could be used and wound up using fewer of the Collaboratory Notebook's inquiry-scaffolding features.

This result points to a complex set of concerns about the adoption of collaborative hypermedia in classroom settings. Our limited experience shows that it is important for teachers adopting such media to clarify and prioritize their expectations for students' work in them and to design assessments which will clarify these priorities for their students. Teachers cannot hope, any more than software designers can, that the design of the new medium itself will strongly influence the directions in which students put forward their effort, regardless of the assessment schemes put in place or the resource limitations under which students work. When weaving collaborative hypermedia into classroom practice, success will depend on the attention paid to the variety of countervailing forces which can work against the expressed and implied intents of the instructional designer.

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Information-Access Characteristics for High Conceptual Progress in a Computer-Networked Learning Environment

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Abstract

The aim of the paper was to examine how elementary school students (grade 5-6) make use of two different types of networked database systems specially designed for intentional learning. Students were allowed to represent their thoughts and knowledge in the form of texts or graphics in the database, then collaboratively manipulate them for improving their comprehension of study topics in the classroom. As a framework for describing differences in the students' activities between those who highly benefited and those who did not, "Information-Access Characteristics (Perkins, 1993)" was considered. Results showed: (1) that students who highly benefited from their activities in the database significantly more engaged in knowledge-transforming activities which are considered critical to high conceptual progress, and (2) that a system affordance which allowed students to conduct their joint writing activities significantly prompted such a transforming activities at a joint-space of their collaborative learning.

1. Problem

Recent cognitive research on students' learning in the classroom has suggested the importance of development of learning environments where students authentically engage in knowledge construction (e.g., Bruer, 1993). Bereiter and Scardamalia (e.g., 1989) argued that students should be supported to engage in their intentional learning. Students bring their own inquiries into their learning activity, then collaboratively pursue the inquiries through building their collective knowledge. What students learn is not consequences from their learning activity based on problems given by teachers, i.e., learning from problem-solving (Bereiter & Scardamalia, 1989), but the learning process itself by which students engage in knowledge-building as effective collaborators in the classroom community.

Computer-Supported Intentional Learning Environments (CSILE) is a networked database system which encourages students' intentional learning through progressive discourse (Scardamalia & Bereiter, 1993). Students are allowed to externalize their thoughts in the database in the form of texts or graphics, then manipulate their represented knowledge in building further knowledge. The database is accessible to anyone who is registered as a member. Students can asynchronously collaborate through mutual commentaries. They can create comment notes to add their reflective thoughts on their friends' thoughts. Thus, students with CSILE work as members of the classroom community in pursuing their inquiries on study topics (Scardamalia, Bereiter, Brett, Burtis, Calhoun & Smith-Lea, 1992).

Because CSILE is a new technology not available in regular classroom learning, students' learning activity becomes much more rich and complex than ever. In CSILE, students are engaged in *overt* knowledge-building by manipulating their knowledge in the form of texts or graphics, rather than manipulating their *internal* knowledge structures. Furthermore, students share their represented knowledge with others so that anyone can build his/her knowledge through coordination of self and others' knowledge. Thus, students' knowledge-building on the network occurs through dynamic interaction among learners and their constructed knowledge database. How do students engage in this dynamic activity? How does the networked database mediate students' learning? These problems are pursued by analyzing students' computer-mediated activities from the perspective of distributed cognition (Salomon, 1993).

Distributed cognition, a recently developed concept, assumes human beings as part of a more global information processing system rather than as independent information processors (Salomon, 1993). Knowledge and mental resources for the global system are widely distributed across people and available tools. Our performance in a complex cognitive task is a process by which the distributed cognitive resources dynamically interact with one another. This process is the core of knowledge-building. Although individual learners cannot know and manipulate all the cognitive resources, they can collaborate with one another in constructing high quality knowledge which does not belong to any specific individuals but to a community of the learners (Bereiter, 1994). In this sense, CSILE is a networked environment where community knowledge is constructed. A goal of students' learning is to contribute to the knowledge-building in their classroom community as well as to advance levels of their understanding (Oshima, 1994). The process of knowledge-building which should be examined in CSILE classrooms is not only a process by which each student *internalizes* external information, but a process by which s/he *engages in knowledge-building in the classroom community*.

How can we describe human beings as part of a global distributed cognitive system? Because traditional cognitive science has focused on representation of human's internal structure, its approach is not appropriate for us to examine students' activity in CSILE. From the perspective of distributed cognition, Perkins (1993) proposed a new level of analysis of human mind, *cognition as information flow*. He defined *person-plus-surround* as a unit of analysis of cognition, and focused on information flow in the *person-plus-surround* system. Here, the focus of the analysis is no longer on how subjects' internal structures are constructed, but rather on how subjects work in the global system. To describe the information flow in a target global system, Perkins suggested the following information-access characteristics of the system:

Knowledge. When the global cognitive system functions in a task, various types of knowledge are used, from content-specific knowledge to higher-order knowledge such as monitoring and planning. In the present study, we focus on different types of descriptive knowledge in the database (discussed later).

Representation. How knowledge is represented is another important aspect. Because CSILE is mainly driven by written discourse, we focus on written form of knowledge.

Retrieval. Although necessary knowledge is represented in the system, it does not mean that we can always access it in a contextually appropriate way. Studies have shown: (1) that experts usually learn necessary knowledge and skills in a quite problem-based situation so that they can easily access the necessary knowledge in their work (e.g., Brown, Collins & Duguid, 1989); and (2) that authentic problem-based learning in a meaningful context can prompt learners' acquisition of knowledge which can be later retrieved in an appropriate way (e.g., Lampert, 1986). Here, we focus on (1) how learners use their own and others' knowledge represented in the database, and (2) how they manipulate the knowledge in advancing their comprehension.

Construction. "Construction" means physical or psychological spaces that support subjects to engage in knowledge manipulation and construction. The places are not necessarily placed in subjects' heads. In a *person-plus-surround*, we can use any available spaces such as a paper, a blackboard, and an electronic document. Recent studies on *effects with intellectual technologies* (Salomon, Perkins & Globerson, 1991) showed that computer support which allows learners to run and see their represented knowledge improves the learners' reflective processes in problem solving and helps them acquire higher levels of understanding (e.g., Nathan, Kintsch & Young, 1992). Here, we focus on two different spaces of collaborative learning in CSILE.

In the present study, we had two specific research questions. The first is what differences are there in information-access characteristics between students who benefit greatly from their activity and those who do not in CSILE. Through pursuing this question, we can acquire information for improving students' activities in such a way that they effectively engage in higher quality of learning. In addition to this, we examined differences in system affordances between the two different system configurations. Because of the system development, students have used different systems in different years. One critical shift in the system was from individual-note based to discussion-note based (Scardamalia, Bereiter, Hewitt & Webb, in press). In discussion notes, students are directed to engage in joint writing activities on a shared problem. Theoretically, it is expected that students can benefit from their engagement in such joint activities. However, it has not yet been discussed how such a shift in the system affects students' activity in CSILE. Therefore, we compared students' activities between the two system configurations.

2. Study Design

2.1. Curriculum Description

The present study examined two fifth- and sixth-grade combined classrooms taught by the same teacher which used different types of systems in two consecutive years. In the first year, twenty-nine students used a version of CSILE (the "first-year system") in which they reported their thoughts on a study topic, electricity, in their individual text or graphic notes. Hence, the database was a compilation of such individual notes. Students organized and advanced self and others' thoughts by accessing and commenting on the notes. In the second year, twenty-seven students used another version (the "second-year system") in which they reported their thoughts on a study topic, force, through dialogical written discourse on their collaborative problems in *discussion* notes. In discussion notes, students proposed problems to pursue and reported their thoughts related to the problems. Discussion notes were expected to have the following effects on students' learning: First, because a discussion note stated a clear problem, students were expected to engage in problem-based learning. Second, because a single note consisted of thoughts shared among students, students were expected to be involved in dialogical writing by reporting their written discourse, following their own discourse and that of others. In each year, before starting their CSILE learning session, they conducted classroom experiments and group work based on materials available in the classroom. The teacher in the classroom helped and encouraged students to collaborate with one another through the database system.

2.2. Data Source

Students' computer actions, such as text- and graphic-generation and revision were automatically recorded as tracking files on a hard disk of a main server. Information used in the present study contained (1) time and contents of text- and graphic-generation and revision, and (2) time and contents of database search. On the basis of the above information, the present study examined how students represented and manipulated the knowledge in the database.

2.3. Measures for Students' Basic Skills Related to Written Discourse Activities in CSILE

Students' basic skills related to their written discourse activities in CSILE were considered to affect their use of the system. Scores of reading, writing, and spelling in the Canadian Tests of Basic Skills conducted at the beginning of the academic year were used as measures of students' basic skills.

2.4 Measures for Information-Access Characteristics in CSILE

Knowledge. Students' written discourse in each note was divided into units of ideas, then each unit was categorized as one of three types of knowledge items. The first is *referent-centred* knowledge (Bereiter, 1992). This is definitional and descriptive information which clearly refers to a concept. It is easy for students to pick out this type of knowledge from their resource materials or their minds. The second is *problem-centred* knowledge (Bereiter, 1992). This is process-oriented information such as causal mechanisms which have potential to facilitate students' understanding. The third is *metacognitive* or *reflective* knowledge. Although it has been considered to rarely appear in an external form (Perkins, 1993), students, here, were asked to write down their reflection on their own learning. Two independent raters categorized the units of ideas (inter-rater agreement was over 90%), then frequencies of the categories were counted.

Retrieval. To analyze how learners manipulated knowledge represented in the database, two types of knowledge change from one knowledge item to another were identified: (1) *knowledge-widening*, and (2) *knowledge-deepening*. Knowledge-widening means that a new knowledge item develops by assimilating information in a preceding knowledge item. Knowledge-deepening means that a new knowledge item develops by accommodating information in a preceding knowledge item (see Appendix). Two independent raters assessed knowledge change from one item to another (inter-rater agreement was over 90%), then proportions of knowledge items which belong to eight categories of knowledge changes were calculated in either the solo-space or the joint-space. Furthermore, students' commentaries were categorized as follows: (1) *knowledge-widening-oriented*, (2) *knowledge-deepening-oriented*, or (3) *information-based*. Knowledge-widening- and knowledge-deepening-oriented commentaries mean commentaries which have potential to change target knowledge items in knowledge-widening and knowledge-deepening way respectively. Information-based commentaries are those which evaluate surface information in written discourse such as grammatical errors and misspelling.

Construction. Students are considered to engage in two different spaces of collaborative learning: the solo-space and the joint-space. The solo-space is a constructive arena where students develop their own understanding. Students' activity in the solo-space was examined by analyzing change in their written discourse from their own preceding discourse. The joint-space is another arena where students contribute to development of understanding in the classroom community. Activity in the joint-space was examined by analyzing change in students' written discourse from others' preceding discourse, and students' commentaries on others' discourse.

2.5. Data Analysis Design

To examine the two questions described above, we used a 2 (Type of Student) X 2 (Type of CSILE) factorial design for analyses of the measures.

Classification of students. Because we focused on students' progressive discourse as knowledge-building, the change in their explanatory discourse in notes from the beginning to the end was used for classification of students. We evaluated learning processes by which learners critically changed their explanatory discourses. For instance, in the initial stage of their learning, most of students did not have explanatory discourse in the sense that they did not have any clear understanding of what to explain. They wrote down their ideas such as "Electricity works because a light bulb is turned on," and "Electricity makes a light bulb light up." As Chi, Slotta and de Leeuw (1994) argued, higher levels of concepts such as electricity and force are not to be learned as matters but as problem-related or process-oriented. As far as students are stuck with the scientific concepts as *matters*, they cannot get into deeper understanding of the concepts. Indications of such a critical shift in epistemological ontology in students' learning processes were searched for as criteria for progressive discourse, i.e., knowledge-building. We sought to assess the variables for causes or effects and the relationships among the variables students considered in their explanatory discourse. Criteria for the evaluation are (1) improvement of scientific power of their explanatory discourse to explain their problems; and (2) degrees of elaboration and clarification of the relationships among the variables used in the explanatory discourse. On the basis of on the criteria, two independent raters assessed the improvement of learners' discourse from the beginning to the end through reading students' notes. Students who reached clear cause-effect relations, then improved their scientific powers to explain their problems were categorized as high-conceptual-progress learners. The remainder of the students, whose explanatory discourses on their inquiries were not conceptually changed during their learning, were classified as naive learners. Eight learners among twenty-nine in the first-year and ten among twenty-seven in the second year were assessed as high-conceptual-progress ones by the two independent raters, and the remaining were defined as naive ones (inter-rater agreement was over .90).

3. Results and Discussion

3.1. Comparison of Basic Skills Scores

A 2 (Type of Students) X 2 (Type of CSILE) MANOVA on the three basic skill scores showed no significant results (Wilks' Lambdas for available effects were .87 for Type of student, .99 for Type of CSILE and .95 for the interaction, all *p*s > .05).

3.2. Frequencies of Knowledge Items

We here focus on referent-centred and problem-centred knowledge items because these types of knowledge items contained information manipulated by students (Fig. 1). To examine differences in frequencies of the types of knowledge items, a 2 (Type of Student) X 2 (Type of CSILE) X 2 (Type of Knowledge) ANOVA was conducted. Significant main effects for Type of Student, $F(1, 52) = 28.6$, $p < .05$, and Type of Knowledge, $F(1, 52) = 9.9$, $p < .05$, were found. High-conceptual-progress learners generated more knowledge items than did naive learners. Furthermore, students generated more referent-centred knowledge items than problem-centred knowledge items.

3.3 Knowledge Change in the Solo-Space (Figs. 2-1 & 2-2)

Widening change in referent-centred knowledge from referent-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed a nearly significant effect for Type of Student suggesting that high-conceptual-progress learners engaged in the type of knowledge change more than did naive learners, $F(1, 48) = 3.8$, $p < .06$.

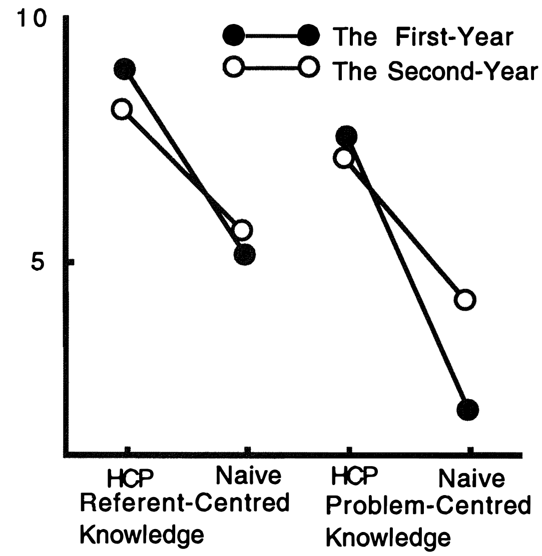

Figure 1. Mean Numbers of Knowledge Items Produced by Students.

Widening change in referent-centred knowledge from problem-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed no significant effects.

Widening change in problem-centred knowledge from referent-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed no significant results.

Widening change in problem-centred knowledge from problem-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed significant effects for Type of Student, $F(1, 41) = 4.8$, $p < .05$, and Type of CSILE, $F(1, 41) = 8.6$, $p < .05$. High-conceptual-progress learners in both years engaged in "problem-centred knowledge" change significantly more than did naive learners. Furthermore, students in the first year engaged in the type of knowledge change significantly more than did those in the second year.

Deepening change in referent-centred knowledge from referent-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed a nearly significant effect for an interaction, $F(1, 48) = 3.6$, $p = .06$. Post hoc comparisons by Newman-Keuls test showed that naive learners in the second year marginally more engaged in "referent-centred" knowledge change than did those in the first year.

Deepening change in referent-centred knowledge from problem-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed a significant effect for Type of CSILE that students in the first year significantly more engaged in "referent-centred knowledge" change than did those in the second year, $F(1, 46) = 4.2$, $p < .05$.

Deepening change in problem-centred knowledge from referent-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed significant effects for Type of Student, $F(1, 46) = 4.8$, $p < .05$, and Type of CSILE, $F(1, 46) = 11.0$, $p < .05$. High-conceptual-progress learners in both years engaged in "problem-centred knowledge" change significantly more than did naive learners. Furthermore, students in the second year engaged in the type of knowledge change significantly more than did those in the first year.

Deepening change in problem-centred knowledge from problem-centred knowledge. A 2 (Type of Student) X 2 (Type of CSILE) ANOVA showed significant effects for Type of Student, $F(1, 41) = 25.6$, $p < .05$, and Type of CSILE, $F(1, 41) = 7.3$, $p < .05$. High-conceptual-progress learners in both years engaged in "problem-centred knowledge" change significantly more than did naive learners. Furthermore, students in the second year engaged in the type of knowledge change significantly more than did those in the first year.

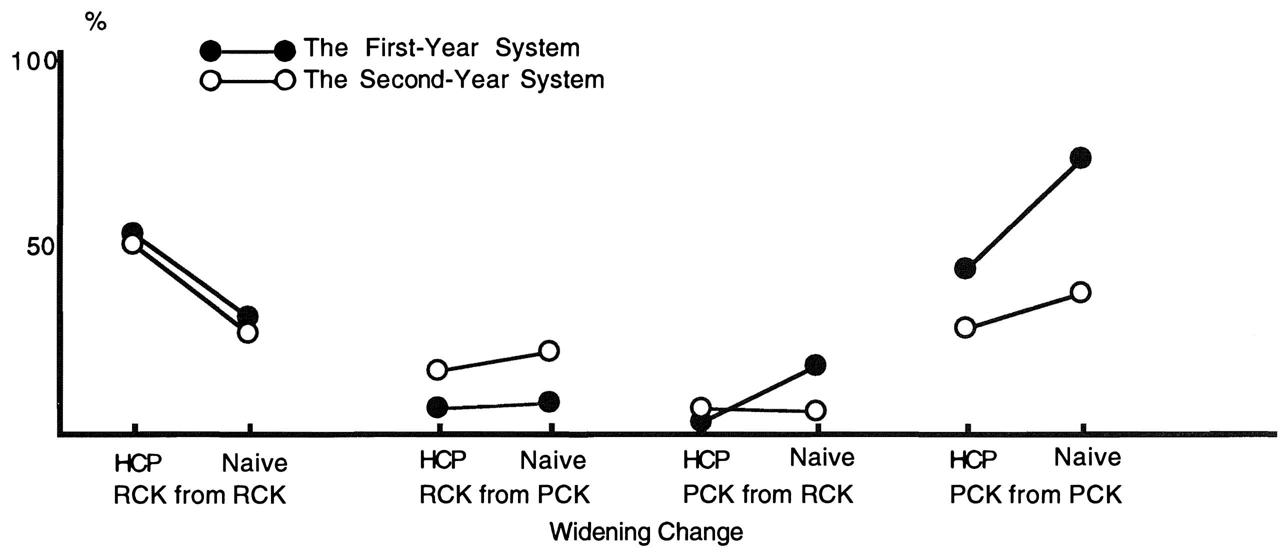

Figure 2-1. Mean Proportions of Different Types of Knowledge Items Produced in a Widening Way.

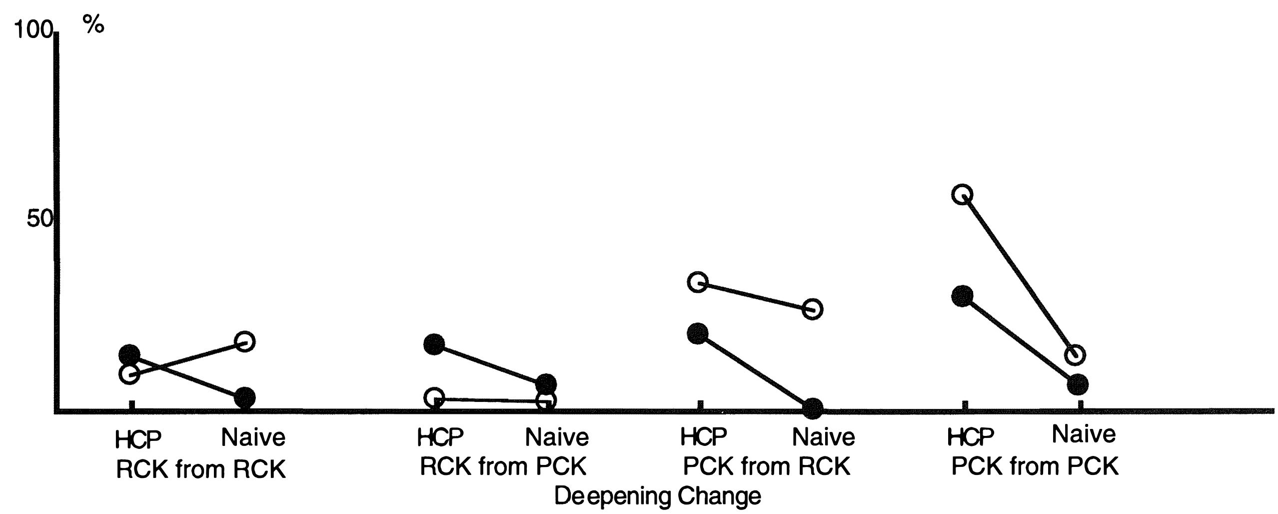

Figure 2-2. Mean Proportions of Different Types of Knowledge Items Produced in a Deepening Way.

3.4. Knowledge Change in the Joint-Space

Although we should have examined exactly the same knowledge changes as those in the solo-space, we had to merge some categories of knowledge changes and use a categorical analysis because of the small size of the data sample. The original 2 (Type of Student) X 2 (Type of CSILE) design was decomposed to simple comparisons.

Comparison of knowledge changes between high-conceptual-progress and naive learners. Since we had little data for knowledge change in the joint-space in the first year (Tables 1 & 2), we merged eight categories of knowledge change into knowledge-widening and knowledge-deepening. Chi-square analyses showed (1) that significantly more high-conceptual-progress learners manifested deepening change in knowledge from others' knowledge than did naive learners, $\chi^2(1, N=23) = 5.8, p < .05$; and (2) that both types of learners equally manifested widening change in knowledge from others' knowledge, $\chi^2(1, N=23) = 1.3, p > .05$.

Table 1. Frequencies of Students Who Showed or Did Not Show Deepening Change in Knowledge Based on Others' Knowledge.

Learners	Deepening Knowledge Change	
	Showed	Did Not Show
HCP	4	4
Naive	1	14

Note. Six naive learners were omitted from the analysis because they did not show any attempt to get involved in joint activities.

Table 2. Frequencies of Students Who Showed or Did Not Show Widening Change in Knowledge Based on Others' Knowledge.

Learners	Widening Knowledge Change	
	Showed	Did Not Show
HCP	4	4
Naive	4	11

Note. Six naive learners were omitted from the analysis because they did not show any attempt to get involved in joint activities.

Table 3. Frequencies of Learners Manifesting Each Type of Knowledge-Change in the Joint-Space.

Proportional Scores	Frequencies of Students	
	Naive	HCP
Widening Change		
RCK from RCK	6 (35.3)	9 (90.0)**
RCK from PCK	5 (29.4)	3 (30.0)
PCK from RCK	5 (29.4)	0 (0.0)*
PCK from PCK	6 (60.0)	3 (30.0)
Deepening Change		
RCK from RCK	0 (0.0)	6 (60.0)**
RCK from PCK	0 (0.0)	7 (70.0)**
PCK from RCK	0 (0.0)	3 (30.0)**
PCK from PCK	0 (0.0)	7 (70.0)**

Note. Numbers in parentheses are proportions. ** and * show significance in chi-square analysis at $p < .05$ and $p < .10$, respectively.

In the second year (Table 3), we analyzed frequencies of students in eight categories of knowledge change. Chi-square analyses showed the following: (1) More high-conceptual-progress learners showed deepening change in referent-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=27) = 8.0$; deepening change in referent-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=27) = 5.7$; deepening change in problem-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=27) = 5.7$; and deepening change in problem-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=27) = 5.7$ (all *p*s were less than .05). (2) More high-conceptual-progress learners also showed widening change in referent-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=27) = 7.6, p < .05$. (3) Marginally more naive learners showed widening change in problem-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=27) = 3.6, p < .10$.

Comparison of knowledge changes between the two systems. Because of the small data sample for the first year, we omitted comparison between the years within each type of learners. Chi-square analyses for comparisons between the years showed the following: (1) More students in the second year showed widening change in referent-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=56) = 10.0, p <$

.05; widening change in problem-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=56) = 4.5$, $p < .05$; widening change in problem-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=56) = 6.2$, $p < .05$; and deepening change in referent-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=56) = 8.6$, $p < .05$. (2) Marginally more students in the second year showed deepening change in referent-centred knowledge from others' referent-centred knowledge, $\chi^2(1, N=56) = 2.7$, $p < .10$; and deepening change in problem-centred knowledge from others' problem-centred knowledge, $\chi^2(1, N=56) = 3.8$, $p < .10$ (Table 4).

Table 4. Frequencies of Learners Who Manifested Each Type of Knowledge-Change in the Joint-Space between the Two Systems.

Knowledge Change	Frequencies of Students	
	First-Year	Second-Year
Widening Change		
RCK from RCK	8 (27.6)	12 (44.4)
RCK from PCK	0 (0.0)	8 (29.6)**
PCK from RCK	1 (3.4)	6 (22.2)**
PCK from RCK	2 (6.9)	9 (33.3)**
Deepening Change		
RCK from RCK	2 (6.9)	6 (22.2)*
RCK from PCK	0 (0.0)	7 (25.9)**
PCK from RCK	1 (3.4)	3 (11.1)
PCK from RCK	2 (6.9)	7 (25.9)*

Note. Numbers in parentheses are proportions. ** and * show significance in chi-square analysis at $p < .05$ and $p < .10$, respectively.

3.5. Frequencies of Commentaries

A 2 (Type of Student) X 2 (Type of CSILE) X 3 (Type of Commentary) ANOVA showed marginal and significant main effects for Type of CSILE, $F(1, 46) = 3.6$, $p < .08$, and Type of Commentary, $F(1, 92) = 5.3$, $p < .05$. Post hoc comparisons by Newman-Keuls test showed that students in the second year generated significantly more commentaries than did those in the first year, and that students in both years generated significantly more information-based commentaries than the other types (Fig. 3).

3.6. Summary of Information-Access Characteristics

Differences between high-conceptual-progress and naive learners. High conceptual progress was associated with frequent engagement in representing knowledge, and engagement in knowledge constructive activities. In the solo-space, high-conceptual-progress learners engaged in deepening change in their problem-centred knowledge as well as widening their referent- and problem-centred knowledge. This suggests that high conceptual progress happens through two types of information flow: knowledge assimilation, and knowledge construction. Through knowledge assimilation, such learners may contextualize new information in their problem situation. Then, they might construct a higher level of understanding through elaboration of information in referent- and problem-centred knowledge. Thus, high-conceptual-progress learners see the database as their externalized problem space, then elaborate that space through their learning activity.

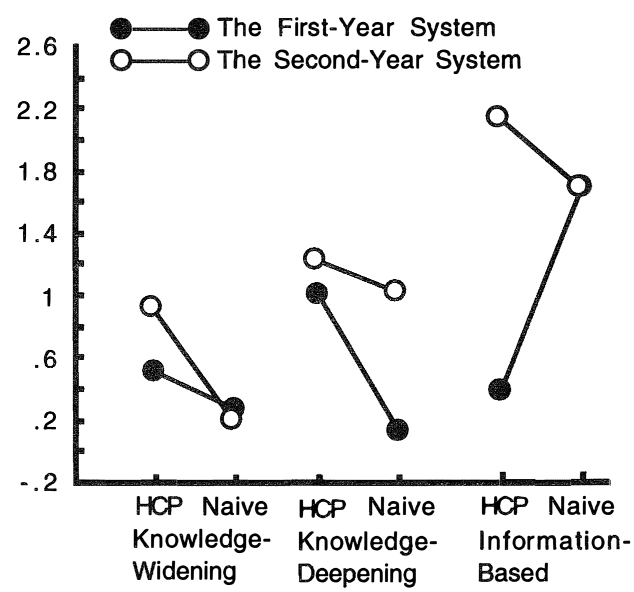

Figure 3. Mean Numbers of Different Commentaries.

The results of comparisons in the joint-space also emphasized the relation of high conceptual progress to students' engagement in deepening change from others' knowledge items. In particular, the results in the second year showed that high-conceptual-progress learners engaged much more in deepening change in knowledge from others' knowledge as well as assimilating others' referent-centred knowledge. These results suggest that high-conceptual-progress learners not only saw their database as their individual problem space, but also created a collective problem space.

Thus, students' active engagement in community knowledge-building consequently advanced their own level of understanding.

Differences between the systems. Differences in system affordances between the two years were quite evident. Students in the first year were much more directed to the solo-space of collaborative learning, whereas those in the second year were directed to the joint-space. This is because the second year's system provided students with discussion notes which have them naturally engage in their joint-space of collaborative learning. Characteristics of information flow engaged by students in the two years were also different in either the solo- or the joint-space. In the solo-space, students in the first year were more engaged in deepening change in referent-centred knowledge, whereas those in the second year were more inclined to deepening change in problem-centred knowledge. In the joint-space, students in the second year were more engaged in deepening change in knowledge and interactive information flows between the two types of knowledge. Problem-centred knowledge-building through interaction between the two types of knowledge is considered to be an effect of the discussion notes. Clearly defined problems in discussion notes are considered to have promoted students' concern with problem-centred knowledge. Furthermore, in the second year, most of students' individual knowledge was represented through peer written discourse centred around the problems. Coordination of their own and others' knowledge through dialogical written discourse might be more effective than individual notes in helping students to focus on information related to their own problems.

4. Conclusion

From the perspective of distributed cognition, the following points are worth emphasizing. First, high conceptual progress was associated with frequent engagement in distributed cognition. Advancement of individual knowledge relied much on distribution of information and active interaction among information sources. Interaction between learners and the database as a type of *person-plus-surround* system helps learners manage their learning processes. In particular, system affordances for students to monitor their thoughts at different times may be powerful. Students can manage distributed information or thoughts generated by themselves at different times. Results of knowledge change by high-conceptual-progress learners in the solo-space support this point. Furthermore, the second-year system also mediated collaborative learning among learners. Students manipulated others' thoughts at different times as well as their own thoughts. Here, distributed cognition occurs in another type of system, that of *people-plus-surround*. Results in the joint-space suggest that students should be aware of working in this type of system.

Second, some specific types of information flow are found to be critical to knowledge-building: knowledge transforming flows such as deepening change in problem-centred knowledge from referent-centred knowledge and deepening change in referent-centred knowledge from problem-centred knowledge. High-conceptual-progress learners were engaged in knowledge transforming information flows significantly more than were naive learners. This suggests that high-conceptual-learners were aware of different types of information and coordination among them, whereas naive learners lack such awareness. System support for naive learners to manage their represented knowledge in an externalized problem space should be further investigated on the basis of findings from cognitive science (e.g., Klahr & Dunbar, 1988).

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Appendix

An Example of Deepening Change in Problem-Centred Knowledge from Referent-Centred Knowledge.

ATOMS
Atoms are made out of protons and neutrons and electrons. In the middle of a atom, there is a ball called neutrons and near that, some balls, that contains electricity, called protons. That part is called the NUCLEUS of the atom. Also there are things that go very fast around the nucleus, they are called electrons. Each particle is either positive or negative. The amount of electricity in a particle is called its charge. A particle with a positive charge and a particle with a negative charge pull weakly at each other if the charges are small and strong if the charges are large.

↓

*** ELECTRICITY***
Try this:
Blow up two balloons. Rub them on a woolen sweater(i might work if you rub it on your hair too) and put on the wall. It will stick to the wall. Why does it stick to the wall? I think the explanation for this is, when you rubed on your woolen sweater(or on your hair), the some of the electrons from the sweater(or your hair) went into the balloon. So then the balloon had more electrons and it gave of the electrons that were extra to the wall. But after a short time the balloon will fall from the wall. That is because the extra electrons in the balloon will leak away

An Example of Widening Change in Referent-Centred Knowledge from Problem-Centred Knowledge.

How I Think Electricity Works
I think electricity works like this:there is electricity stored in a battery,and when you hook up a wire to that battery,and to a light bulb,the electricity from that battery runs through the wires,and into the light bulb,and the light bulb lights up.

↓

How I Think A Circuit Works
To make a light bulb light up,there has to be some kind of electric circuit for the electricity to run through. A circuit is usually made up of a few batteries,two wires and a light bulb.

A Qualitative Examination of an Interactive Computer Program on Multiculturalism

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Abstract

The use of interactive technology is entering instructional domains that have never before considered the use of advanced technology. One of these domains is the area of multicultural education, or diversity training. In the past two years, three different hypermedia programs have been developed to use on college campuses for diversity training. Two of the programs, developed at Miami of Ohio and Vanderbilt, utilize laserdiscs to present information and case studies for practiced decision making (Wilson, 1994). The third program was developed by the researcher at the University of Virginia and is the subject of this preliminary study.

Keywords — multicultural education, diversity training, interactive technologies, hypermedia.

1. Background

1.1. Multicultural education

Multiculturalism is the state in which one has mastered the knowledge and developed the skills necessary to feel comfortable and communicate effectively with people of any culture, and in any situation involving a group of people of diverse cultural backgrounds (Pusch, 1979). Multicultural education is the process of integrating the viewpoints of many cultures into the educational process. Multicultural education (also referred to as diversity training) also takes the role of helping individuals in the university community (students, staff, and faculty) to increase their ability to communicate and work with people from many cultures.

There are three basic components to diversity training (Lee, 1983). First, the training must be structured and the learning process organized. Second, the information should introduce new subjects and be presented in new, imaginative ways. Third, the training should also emphasize human interaction. Many other multicultural educators agree that the third component of interaction can have the greatest impact on training.

Diversity training also needs to show students how to apply the knowledge and increased awareness they have obtained. Strategies for this part of training can either be individualistic, or group-oriented. Students can acquire cultural knowledge from a variety of sources. Much of the training revolves under individualized instruction, including self-study, audio-visual presentations, and lectures (Sue, 1991). On the other end of the discussion spectrum, students can put into practice their new knowledge base by participating in role plays, simulations, and conflict resolution (Brown, 1985; Junn, 1994).

1.2. Hypermedia's relationship to multicultural education

Lee's (1983) three guidelines for designing effective multicultural training also blend with the features of hypermedia. First, the learning must be organized and structured. Although the order in which the information is accessed is within the control of the student, hypermedia is highly structured so users can access the correct information at the appropriate time. Second, multicultural information should be presented in new ways. Interactive media itself is unique learning tool to many students, but beyond that, each interaction with hypermedia can be new and different for the user. Finally, Lee emphasizes the need for interaction. Hypermedia requires the user to interact with the computer and the information. The learner can't sit passively and watch information cross the screen. The user must take action with the computer in order to gain information. Ridley (1994) also stresses the importance of interaction to forward the process multicultural education.

2. Methodology

2.1. Participants

Sixteen participants were solicited from an undergraduate education methods course and from student organizations and randomly assigned to one of two groups, eight students to each group: 1) Using the program with a partner (Paired Discussion or PD), or 2) using the program alone followed by a facilitated group discussion (Facilitated Discussion or FD).

2.2. Materials

The base of the research study revolves around the use of a computer program entitled "Managing Diversity" developed by the researcher. The program is interactive in nature and uses music, graphics, sound, text, case studies, games, and personal reflections to provide a framework for learning about multiculturalism. The learner can choose to explore Multicultural Theory, practice multicultural decision-making through Case Studies, or hear personal thoughts about the importance of multiculturalism from people who work in the field as part of the section entitled Personnel. The section on Multicultural Theory offers the learner additional choices such as learning about Cultural Differences, playing a game called Acrostics, learning how to Lead a Multicultural Group, or delving further in Multicultural Development. Throughout many of these sections, users are presented with the opportunity to react to what they are reading and hearing by typing in their responses and thoughts. The final section of the program takes the student a step further into making a commitment toward multiculturalism -- a multicultural contract. Learners can type in three things that they plan do during the next three months to promote multiculturalism.

2.3. Procedures

Students were randomly assigned to one of the two study groups The students in the PD group were told they could spend as much time as they wanted with the program and explore any part they wanted. The only requirement was they must agree as a team what to investigate and when to quit. The students working as individually with the computer in the FD group were also told to spend as much time as they wanted and stop whenever they wanted. This study group was also told that upon completion of the program, they would move to another room and participate in a 15-20 minute discussion. Students were observed while using the program and notes were taken on the parts of the program they used, as well as any discussions. Two trained multicultural facilitators were used for the FD. The facilitators raised issues of awareness (e.g. "How do you define racism?" and "what do you think about diversity at this university?"), and challenged students to accomplish developmental tasks (e.g., "Would you attend a party sponsored by students from another culture?"). Finally, all student's were interviewed and audio-taped at the end of the study..

2.4. Data analysis

All information gathered was qualitative in nature. Data analysis was done by first transcribing the tapes from the post-instruction interviews. The transcripts of these interviews were examined by first comparing answers given by all participants to each question and grouping these responses within themes/categories. Observation notes were also examined and grouped into categories. Four categories or themes emerged from this analysis and they are presented below.

3. Results

3.1. Does the program help the understanding of multiculturalism?

The main goal of diversity training is to promote the understanding of multiculturalism and the importance of being multiculturally aware (Ridley et al, 1994). All students in the study reported that they felt the program and associated activities helped develop their understanding.

However, the FD students reported that most of their new understanding came from the discussion, rather than the use of the program itself. Participants felt that the facilitator was able to bring real-life situations to the topic. The following quote is representative:

> *The program helped you understand things but the discussion made it real, by talking about real people and situations.*

The PD students felt the program helped their understanding of multiculturalism through their partner. The program provided them with a great deal of information, and it was through the processing that information with a partner that understanding was enhanced. For some of the PD students, it was the individual differences between the two partners that increased understanding:

> *Multiculturalism focuses on knowing a lot about different cultures and understanding how different people perceive these cultures. You and your partner had different views, [so you can] see already why certain prejudices exist. Like, I had different ideas... just like she did and I got input to her ideas and how she might see different things and she got that from me. So I guess it's good ... to get two views on some of the topics [we] discussed on the computer.*

Other student felt that understanding was enhanced when paired with someone sharing similar beliefs. One woman reported:

> *...I had a partner who didn't think the same as I did, and I didn't know the boundaries. That's part of the problem with multiculturalism. You don't want to admit how racist you really are...or have someone discover the things that you hide. I wouldn't want to come to some self-realization with someone I didn't know right there.*

Another student concurred with that thought. She had worked with someone similar and appreciated that they did not hold different belief structures:

> *[My partner] and I have basically the same beliefs about multiculturalism. It would have been difficult if one person was very open-minded and the other person was prejudiced, that wouldn't have worked.*

Despite these comments, observations of both groups found that students of different backgrounds and cultures encourage better understanding of multiculturalism. On one occasion, a female student in a PD shared her experience at going to high school in a predominately Orthodox Jewish school. Within the FD, an African-American student was directly queried by the group about her experiences and thoughts. In general, it appeared that the important component that promoted understanding was the ability to interact with other persons, whether through PD or FD, about the information on the computer.

3.2. The discussions

As noted above, discussion was an important component to this learning experience on multiculturalism. The students in the FD reported that making the information real through discussion was important. Students felt that the facilitator provided alternative avenues to work with and interpret the information they gathered first individually.

> *I think I prefer the one-on-one with the computer first, and then broaden the information with a discussion, or interaction about it.*

> *Like I told [the facilitator], it was nice to be able to see it by yourself the first time.*

However, one FD student indicated that she had instituted a partnership with another student who was also working alone on the computer.

> *I found myself discussing things with the girl on my right because I knew her. I think that helped [me process the information].*

Although only one student reported in the interview that she had discussed information with others, it was observed that most of the students working alone interacted with others sitting nearby at several points during their time on the computer. Sometimes these interactions were to find help with the mouse or how to navigate the program. More often, the FD students shared information with each other about the program. Students were overheard telling others about some "neat music" they had just found, or giving pointers on the game. Two students compared responses on one of the case studies.

The PD students for the most part felt that the discussion with their partner was important to their experience.

> *...Before, I went to a school that was forty percent Jewish and I was really interested to see what [the program] said about Jewish people and then I shared my experience [with my partner].*

> *We were very analytical about a lot of things. We talked about personal experiences.*

> *We talked about whatever came on the screen, sometimes we laughed about things.*

> *I think if people want to discuss it's better to do it [during the program use] instead of waiting, while you've got everything right there in your mind...*

This last quote shows one of the main differences between the FD and PD discussion. The discussions with the PD group was more frequent and spontaneous. Discussions were continuous and took on an air of encouragement. One partner would encourage the other to type in a response to a question, or to manipulate the mouse for a time. No pair held the same type of discussion as another pair. PD students felt comfortable at seemingly going off the topic for a time, but always managed to bring themselves back, and actually added to the conversation.

In contrast, for the FD group, the facilitator spoke at least half of the time. Students would eventually chime in with their thoughts and reactions when prompted, but not initiate a conversational thread. FD students seemed more conscious of directing their comments directly to the topic of multiculturalism and the facilitator.

Generally, all students seemed to value the opportunity to engage in a discussion related to multiculturalism either during the interaction with the computer or after. As shown, even those students who were not placed with a partner self-initiated a partnership during use of the computer to aid understanding of both the computer and the content.

3.3. Interaction with the computer

One of the most exciting aspects of the study was to observe the students interact with a computer. Several of the students were visibly dismayed to discover that their exploration of multiculturalism involved the use of a computer.

> *When I walked in the door, I looked at her and said "Oh no, this isn't a computer thing is it? I hate computers...*

Other students had difficulty using the mouse at the beginning and general difficulties using a computer. However, usually within five minutes, students in the PD group appeared to have overcome these problems and were energetically pushing forward. The same student who was dismayed at first, ultimately found the program enjoyable:

> *When I got going I thought, "Wow, this is fun." I've used computers to type papers...I really do not work well with computers. But I really enjoyed this program. It was very easy to follow. And it was interesting.*

Some students expressed satisfaction with the variety that the program could provide:

> *I liked the voices on the screen. That really added to the program a lot. I liked the quotes, like Martin Luther King and others.*

> *There was some stuff that was really getting you to think about situations and there was some stuff that was just educational, ... there was enough balance that kept me interested to go on and see what the next box was like.*

The PD students were able to use their partner to find more information. Partners were observed encouraging one another to go further and explore more. Many times, a partner would notice a button that the other person hadn't, and the pair would decide to investigate. On several occasions, one partner would start to lose interest and be ready to quit, but the enthusiasm of the other person would reinspire him/her to continue. Additionally, students who weren't comfortable with the computers were able to rely on their partners to help them along the way. When the program allowed the user to type in a response, PD students were more likely to add their thoughts.

In contrast to the PD, it was observed that if a person working alone was not comfortable with the computer, s/he did not investigate all sections of the program. Two FD students had difficulty moving the mouse. Therefore, they chose buttons and menus near the original mouse position. Only a couple FD students added comments when prompted. The other students in the FD treatment either did not find the comment boxes, or could not figure out how to type into the boxes.

4. Discussion

Multicultural educators are in agreement that interaction is an important component of diversity training. The results of this study seem to support this notion. Students in each group both reported and were observed interacting with other individuals while using "Managing Diversity." Even though the FD students knew that they would be having an opportunity to talk about multiculturalism in their group, they still sought out other people for discussion. The conversations in the PD group focused more on sharing information and experiences about multiculturalism, while the interaction during computer use for the FD students seemed to be more of encouragement with the computer. Discussion also seemed to serve the purpose of drawing the information together. They first saw the information on the computer screen, and then pulled the bits and pieces together in the discussion, either formally or informally.

Diversity training must also be new and challenging. The use of hypermedia seemed to fill that role for these students. Students reported that the program helped their understanding of multiculturalism, and the discussion furthered understanding. The program also offered surprising features they hadn't expected. The special abilities of hypermedia to include sound, graphics, and music provided an excitement at interacting with the information.

5. Implications for Future Research

The results of this study indicate a need for further study on the use of interactive media in multicultural training. Students reported that discussion was important for increased awareness, more quantitative measures would be necessary to determine if the perceived increase took place. This study explored the use of more traditional facilitated discussion following the use of the program. Future exploration could study how the use of the program by a facilitator during a discussion affects knowledge and awareness.

Finally, this study did not separate the students' individual use of the computer from the facilitated discussion. It is possible that students gained quantitatively and qualitatively as much from just using the program, and the following discussion didn't really add increased awareness and knowledge. Through more inquiry into this topic, one can better understand the role interactive media can play in multicultural education.

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Teaching IS Design and Development in a Group Learning Setting

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Abstract

This paper describes the instructional approaches for an eight-week, team-based computing project used to teach the principles of information systems design and development to all undergraduate business students at the State University of New York at Buffalo. Three aspects of the project relevant to group learning environments are discussed:

- the process used to form skill-balanced teams,
- the use of scenarios to elicit system requirements (a nontraditional approach), and
- the use of an iterative, six-phase rapid proto-typing process.

The paper concludes with a description of the collaboration technology to be developed to support the prototyping process and instructional approaches described in the paper.

Keywords — cooperative learning, project-based learning, computer-supported collaborative learning, educational groupware, scenario-based requirements, rapid prototyping process.

1. Introduction

A common attitude among information systems (IS) educators is that we should teach undergraduates conceptual skills[1] and leave the learning of practical, or technical, skills[2] to the workplace [15]. This attitude creates a near-crisis situation: the majority of business graduates enter the workplace without the most basic technical skills they need for their jobs.

The ever-increasing demand for graduates with technical IS skills is a direct consequence of pressure from three trends. First, the shortage of computer science graduates [1] [5] means that businesses are being forced to hire more business and liberal arts graduates for their entry-level positions [13]. Second, the ubiquitous application of information technology in every aspect of business operations [1] [22] means that even students who are not IS majors may at some point in their careers work on a corporate re-engineering project, be involved in decision-making activities associated with the building of a strategic informatio 16pate in the definition of an enterprise-wide computing solution. Third, the proliferation of fourth-generation programming environments means that more firms are using prototyping techniques to develop their IS applications [6], and these environments can be used successfully by non-programmers.

How can we better prepare business graduates for these workplace demands? The School of Management at the University of Buffalo (UB), like most business schools, requires all its undergraduate business students take an introductory course in information systems. For most students (all of the non-IS majors), it is the only IS course they take. The UB course is a technical,

[1]Conceptual skills address organizational issues, such as the overall organizational design of information systems, the relationship of the IS function with other organizational functions, and the organizational impact of informations systems.

[2]Practical skills address issues in the management of systems development, such as feasibility and justification, the systems life cycle process, information requirements, prototyping, integration of systems, restructuring of existing systems, project management, configuration management, and systems implementation.

hands-on course designed to develop both conceptual and practical IS skills. In the course, students learn how to use fourth-generation software packages for solving business problems. They also learn about and use two electronic communication tools: Usenet news and email. Required work for the course includes two spreadsheet assignments, two relational database assignments, and a team computing project.

The focus of this paper is on the computing project, as it provides a group learning context for developing students' team skills and their systems design and development skills. The project is authentic and demanding in that it requires multiple complementary skills not commonly found in a single individual. Students with differing strengths and weaknesses must learn how to work together in order to produce a satisfactory product.

Three aspects of the project relevant to group learning environments are discussed in this paper:

- the process used to form skill-balanced teams,
- the use of scenarios to elicit system requirements (a nontraditional approach), and
- the use of an iterative, six-phase rapid proto-typing process.

We conclude with a description of the collaboration technology that we plan to develop to support the prototyping process and instructional approaches described in the paper.

2. Team Computing Project Overview

The computing project accounts for 40% of the typical student's total effort for the course. Team members must develop a prototype information system using a database management system; write a term paper describing their prototype; and give a 20-minute presentation, including a live demonstration of their prototype, to the class.

Ideas for the project are proposed by the students and subject to approval by the teacher. Examples of systems that have been prototyped in our classes over the past two years include a system for tracking customers' print orders as their film goes through the photo-finishing process, a home-video library manager, a system for selecting seats and purchasing tickets for cultural events, an airline baggage tracking system, a perpetual inventory system for a golf store, an apartment locator, a system for scheduling swimming pool service calls, a system to expedite emergency room check-ins, a system for reuniting lost pets with their owners, a feed management system for a race horse stable, a system for tracking fitness club memberships, a football player recruitment system, and a car pool system for matching drivers and riders.

The project engages students in intensive investigation efforts, qualifying it as a project-based learning experience according to the criteria set forth by Blumenfeld, Soloway, et al. [2]. Students are motivated because they pick an application that personally interests them and that addresses a problem they have experienced in their lives. They pursue solutions to nontrivial problems by debating ideas, asking questions, designing plans of attack, observing and analyzing the outcomes of their prototyping experiments, and communicating their ideas and findings to others. Particularly important for motivation, their efforts ultimately lead to the creation of the three tangible (and significant) artifacts: a *working* prototype, a paper, and a presentation.

Another important motivational consideration is grading. We use criterion-referenced, or mastery, grading methods [8], which we have extended to team projects [18]. Criterion-referenced grading, which uses grades to measure students' level of mastery of the subject material against a stated standard rather than to rank them within the class, has profoundly altered the attitudes of both students and teacher so that learning has become what Koschmann [11] calls an 'active process.'

3. Team Formation Process

In the sixth week of the course, after important introductory material has been covered, one class meeting is devoted to an hour-long team skills exercise in which the students sort themselves into teams of five (our classes have 60 to 70 students). The exercise helps the students form skill-balanced teams so that each team has members with the five skills important for successfully undertaking the project: programming, speaking, writing, research, and process skills.[1]

The exercise starts with a teacher-guided discussion of the goal of the exercise, which is for each person to join a high-performance team.

> "Being a member of a high-performance team is one of the most exhilarating experiences you can have. The founding fathers who wrote the U.S. Constitution... the team of scientists who put the first astronauts on the moon... the computer design team in Tracy Kidder's *The Soul of a New Machine*... all of these examples are high-performance teams that we continue to talk about and admire. One distinguishing attribute of a high-performance team is that it *consistently* achieves outstanding results... what are some of the other qualities of a high-performance team?"

[1] Instead of letting the students pick their team members, we have also assigned teams using skill data from a questionnaire that asks each student to rate him/herself on the set of team skills important for the project. See [19] for details.

The class usually chooses a sports team to think about the attributes that distinguish it as a high-performance team. As the students identify attributes, they are written on the board where everyone can see them. The importance of complementary skills always comes out in the discussion, and this provides the segue into the next step of the exercise.

We ask all of the students who feel that leadership is one of their skill strengths to stand. This is a safe, unintimidating way to begin the team formation process, because about half of our students rate themselves as having leadership skills.[1] We talk about the role of the leader in a high-performance team and the fact that it is often a rotating responsibility [10] [19], but "just to begin the team formation process today, we will seed each team with a strong leader." The people who are standing are asked to decide quickly among themselves which of them will start forming teams (the number of teams depends on class size). At this point, one-fifth of the class, slightly fewer than half of the leaders, are left standing; the others sit down.

The remaining students are instructed to organize themselves into five equal-sized skill groups in designated parts of the room. The skill groups are Speakers, Programmers, Writers, Researchers, and Process Experts. The students quickly sort themselves into the groups, but rarely are the groups the same size (usually there is a shortage of Programmers and Speakers). Many students have more than one skill strength, so simply reminding them of this and encouraging the multi-skilled students to move to an undersized group is all that is needed to get the desired balance.

Next, the leaders visit the groups to interview people for their teams. The leader is reminded to consider his/her own skill strengths (other than leadership) in forming the team. We encourage all the members of the growing team to participate in the interview process.

At the end of the exercise, the students have organized themselves into 12 to 14 teams of five such that each team has a set of people with complementary skills important for completing the project. Perhaps even more importantly, the students have already learned a great deal about each other, and they spend the last 10-15 minutes of the class period in their teams discussing project ideas.

4. Prototype Development Process

The project requires eight weeks and uses a rapid prototyping process consisting of six phases (each phase will be described shortly). Figure 1 shows the project time line by course week. The teacher's approval is required before a team proceeds from one phase to the next.

For most students, the project is their first programming experience. The primary goal of the project is to give students an appreciation of (by doing) what is involved in the development of an information system, not to create an entire class of programmers. Not only do the students learn some basic system development skills, but they also are introduced to several IS design principles and methods. They have to learn the principles and methods well enough to apply them to their projects. The teacher must be willing, and able, to provide ongoing coaching to the teams.

The project is difficult for most students and we talk about why. System design is a 'wicked problem' [3] [20]. In contrast to 'tame problems,' wicked problems have no definitive formulation, no stopping rule (the projects are never really done; they can be refined and improved ad infinitum), solutions are not true-or-false (they are good-or-bad; we use terms like "good," "better," and "good enough" to evaluate them), and every one is essentially unique (no two projects are the same).

Wicked problems, because they have no definitive formulation, cannot be solved in a straightforward manner. It is therefore to be expected that a team will gain a better understanding of an earlier project phase when doing a later one. Teams are encouraged, and expected, to turn in revised versions of earlier phases whenever they feel the need to refine or redo them. Many of the teams in our classes redo their requirements and database designs two, three, and even four times. Figure 1 depicts this iterative property of the process: the bars for the requirements and design phases have refinement extensions, and each phase (bar) in the project overlaps at least one other phase (bar).

The teacher must give careful thought to the system software that the students use for developing their prototypes.[2] Most modern database management systems provide decent fourth-generation programming tools, which make these systems accessible to non-programmers. The selected system should provide a range of useful application development tools, such as report generators, data-entry screen generators, high-level menu management functions, and easy-to-use run-time debuggers.

[1] On average, 47% of the students in our undergraduate IS classes have self-assessed leadership skills. The rare skills are programming (13%) and speaking (20%). These statistics are the average of the class averages from four semesters of skill questionnaire data collected from the author's sections of the course.

[2] In a real systems development situation, the students might have to make this decision; but the limited time for the project and the background of the students precludes this.

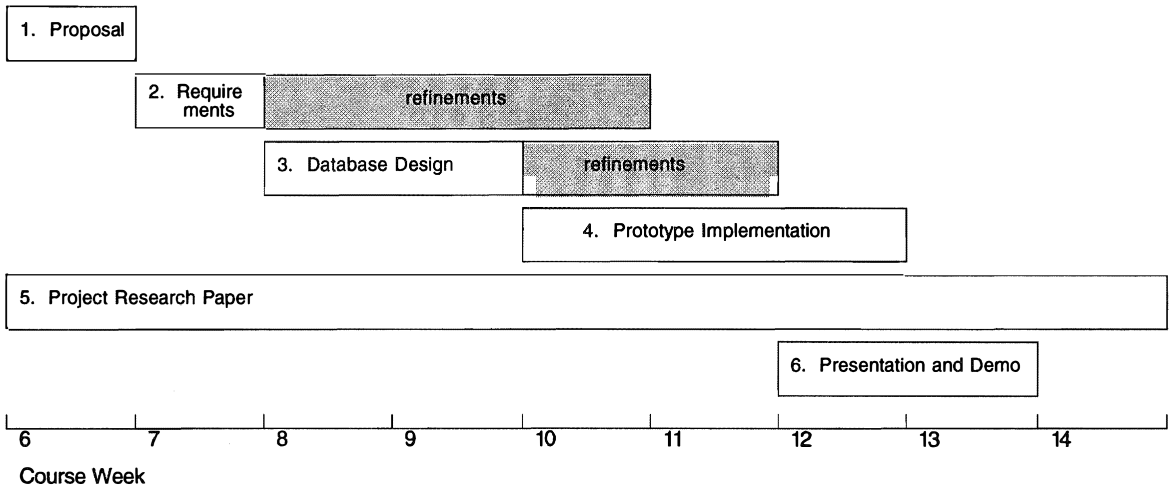

Figure 1. Project phases.

4.1. Phase 1 — Proposal

In Phase 1, each team writes a proposal, which is a brief statement (one or two paragraphs) of the problem or application to be considered and researched. Teams are instructed to focus on answering *why* and *what*, not how, questions. We suggest students start with a problem or frustration they have experienced (e.g., losing baggage in an airport) and then think about how an information system might resolve the problem. The best projects are those that are problem-driven, not technology-driven.

4.2. Phase 2 — Requirements

In Phase 2, the teams identify the functional requirements of their systems. They think about who would use the proposed systems, what information the systems should provide, and how the information might be used. In this project phase, the teams are instructed to focus on answering detailed questions about *what* their proposed systems will do, rather than how they will do it.

The deliverables from this phase are a scenario and a context-level data flow diagram (DFD). The scenario is a vignette that describes a real-world situation, both before and after the proposed information system exists; the DFD clarifies the system's boundaries and how it interacts, from a data perspective, with the end-users of the system. Students are instructed to write the scenario before attempting the DFD.

4.3. Phase 3 — Database Design

In Phase 3, each team creates a database with at least two relations and populates it with a combined total of at least 50 records. A printout of the database and supporting documentation is submitted for teacher feedback. The supporting documentation contains descriptions of each of the fields in each relation, the team's rationale for its database design decisions, and "proof" that its relations are in third normal form. Frequently, a revised or refined scenario and DFD are turned in with Phase 3.

4.4. Phase 4 — Prototype Implementation

In Phase 4, the teams implement the functions described in their scenarios. To meet the project requirements, their implementations must have a minimum of five well-commented procedures. They turn in diskettes of their prototype systems and printouts of all data files and programs. We also ask the teams to turn in current iterations of Phases 2 and 3 and any other supporting material with their project diskettes.

4.5. Phase 5 — Paper

In Phase 5, each team prepares a final report that includes everything from Phases 1 through 4 (in a refined, final form) and additional relevant material from its research. A detailed handout describing the required sections of the paper is given to the students.

4.6. Phase 6 — Presentation and Demonstration

In Phase 6, each team gives a 20-minute presentation of its project to the class. Each presentation includes a discussion of the technical challenges the team encountered in developing its prototype and a live demonstration of the prototype.[1]

The room is charged with emotions on presentation days. The students presenting are nervous and excited; the rest of the class is attentive, interested, supportive,

[1] Our classes are taught in a modern, multi-media equipped classroom. The prototypes, running on a 486 computer housed in the lecturer's podium, are projected onto a large public screen.

and encouraging. As one student put it, "This computing project is a really intense project. At the end, it's fun to show off something you've worked hard on; and it's interesting to see what the other teams have produced." The presentations are the high point of the project, and most of the teams are rightfully proud of their prototypes.

5. Central Role of the Scenario[1]

The scenario, first generated in Phase 2 and refined in Phases 3 through 6, is at the very core of the prototyping process used for the computing project.

At first (Phase 2), most students are reluctant to write a scenario. This reluctance is not surprising: requirements analysis is one of the most difficult activities in information systems development [4] [23]. It is difficult for people to conceptualize and then describe their information needs in terms of system functions.

It is critically important that the teacher encourage students to be explicit. The scenario must describe actual events, including people, their dialogs, and even numbers, where appropriate. The more explicit the scenario is, the more it helps the team focus on a useful, demonstrable subset of functions for its prototype. Without an explicit scenario, members of the team attempt to implement more than they can manage—they can easily end up with a prototype that tries to do everything, but that does nothing well. The team should not be allowed to move to Phase 3 until an adequately explicit scenario has been written.

Once explicit, the scenario gives the members of the team a concrete mental image of what they are building. This image guides them in their database design decisions (Phase 3) and helps them focus their implementation efforts (Phase 4). As work progresses through both these phases, the scenario is continually refined and made more and more explicit.

Most of the teams dramatize their scenarios to demonstrate their prototypes (Phase 6). The pressure of having to demonstrate prototypes makes many teams add significant final refinements to their scenarios. Many creative and entertaining scenarios have been presented, most of them making the prototypes appear to do more than they really do.

The scenario serves an important new purpose at the final stage of the project: it creates powerful mental images of the possibilities suggested by the prototype in the minds of the viewers. In the classroom setting, the viewers are other students in the class; but in the workplace, the viewers would be end-users or project sponsors.

[1]For an example of a scenario, please write the author.

6. Collaboration Technology

Currently, the computer in the UB computing project plays a 'passive role' [16] with respect to the collaborative learning experience. The database management system (DBMS) software that teams use to develop their prototypes is the primary computer-based component in the project. This software is designed for individual use—it does not have any special properties that allow it to support the collaborative learning process.

The learning process is managed by the teacher through interactions with the teams. The teams' progress is tracked by means of an elaborate spreadsheet, using labor-intensive manual procedures to record activity events. It is also necessary to maintain files of photocopies of the deliverables from each stage for each team—these files are, in essence, the only project repositories to which the teacher has assess (for the teams, their diskettes are repositories).

We are in the early stages of designing a two-layered, computer-based, collaborative system to support both the prototyping process and the instructional approaches described in this paper. The inner layer will support each team in the prototype development process. The outer layer will support the teacher in coaching the teams and tracking their progress.

For the inner layer, we plan to build a shell around the DBMS that will provide *activity-level coordination*[2] functions to guide each team through the six-phase rapid prototyping development process. Since a team may be (and usually is) working on more than one phase at a time, the shell must support *multiple endeavors*. We also have plans for developing a *single-stage* groupware editor that will support multiple people simultaneously writing a scenario. The editor will provide *object-level coordination* of the objects (e.g., the characters or roles, their scripts, and the functional requirements) that make up explicit scenarios.

For the outer layer, we plan to build an *activity-level coordination* system, based on electronic mail, which will allow the teacher to receive deliverables from the teams and return them with comments. This layer will be more complex in that it must ultimately provide *total inspection* capabilities, allowing the teacher to observe the progress of the teams' projects (i.e., the *endeavors*) in the inner layer. Eventually, this system should provide *second-order inspection* capabilities, reporting on statistics of interest such as the average time it takes the teams to complete each phase and the average number of iterations for a particular task or phase.

In summary, we note that the two-layer system described above provides support for all forms of commu-

[2]Italics in this and the next paragraph are concepts defined in Ellis' and Wainer's "Conceptual Model of Groupware" [7].

nication *and coordination*[1] that characterize 'active learning processes' [11] [12]: 'peer-to-peer,' 'student-to-teacher,' and 'teacher-to-student' [17]. Specifically, the inner layer of the system provides a 'computer-mediated learning environment' [16] for peer-to-peer communication and coordination,[2] and the outer layer of the system supports teacher-to-student and student-to-teacher communication and coordination.[3]

7. Conclusion

Business information systems are developed in a variety of ways. They may be created by integrating purchased pieces, by building them from scratch, by modifying existing systems, or by a combination of all or some of these development strategies. It is important that business students learn practical problem solving approaches so they can more effectively tackle the problems they will face in their jobs. In particular, all business students (not just the IS majors) need the experience of building a system as team members [14] [22] using "real life" software tools [13].

In this paper, we have described an eight-week, team-based computing project used to teach the principles of information systems design and development to all undergraduate business students at the State University of New York at Buffalo (UB). Although it may be standard practice to teach IS design and development principles using project-oriented courses that require a prototype, a paper, and presentation, the literature does not contain many papers describing these projects.[4]

The UB project requires that students work in teams to develop demonstrable, prototype information systems using a database management system similar to, or the same as, what businesses use to develop their applications.[5] The learning that happens is a 'constructive process' [21], and it develops students' practical and technical skills in many ways. For example, they learn system development tactics such as incremental coding techniques. They learn how to read technical manuals and apply what they read to solve real world problems. They even indirectly pick up technology evaluation skills: the experience of developing an application generates an awareness of what to look for when selecting hardware or software products. When they enter the workforce, the majority of our students may develop IS applications only for their own use and never for use by others (most of the students are not IS majors), but after completing this course they will have gained an invaluable appreciation for what IS can and cannot do and how complex it is to create a useful system.

Our future research will explore the technical issues of how to build the computer-based collaborative system described in Section 6, as well as many usage and process issues. With regard to latter, we believe that we are onto something exciting and promising with the scenario-based process approach. An empirical study by Zmud, Anthony, and Stair [23] provides modest evidence that mental imagery protocols may outperform traditional approaches for eliciting requirements in ill-structured task contexts, but more empirical work needs to be done. Above all, we hope this paper leads to future collaborations with behavioral and educational experts.

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[2]Students will not be able to see any of the outer layer.

[3]The teacher will be able to see the entire inner layer.

[4]In the only paper we could find that describes a project-based IS course, Farah [8] describes a series of projects that prepare his students for their final project, an analysis using real sponsors (our project has no required sponsors). Two other differences between the Farah projects and the UB project are worth noting: (1) the Farah projects are for a systems analysis and design course for IS majors; the UB project is for all undergraduate business students, most of whom are not IS majors, and (2) the Farah projects end with a system proposal and feasibility study (equivalent to Phase 2 of the UB project); the UB project requires students implement a prototype of the system.

[5]The project does not use real project sponsors. If more time were available for the project this would be a important extension, making the project even more realistic.

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Project CIRCLE: Student Mentors as a Strategy for Training and Supporting Teachers in the Use of Computer-Based Tools for Collaborative Learning

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Abstract

This presentation summarizes the training, strategies and results of the use of high school students as mentors to teachers who are implementing new computer-based tools for collaborative learning. The student mentors are an important component of Project CIRCLE, a unique university/public school partnership designed to explore the use of networked environments to support collaborative learning; and model constructivist uses of technology in the classroom.

Keywords — teacher, support, mentors.

1. Introduction

New tools to support collaborative intellectual work have transformed ways that people work and learn together in business, science, government and other settings. These tools are now being introduced into K-12 settings but their use poses two challenges. First, for many teachers it requires a significant change their role as teachers and the way they organize learning activities within their classrooms. Secondly it requires that they learn to integrate network-based tools for collaborative intellectual work into the instructional process. Both of these challenges are addressed by *Project CIRCLE* (**C**ommunity of **I**nformation **R**esources and **C**ollaborative **L**earning **E**nvironments), a collaborative university/public school project funded by the U.S. Department of Education Secretary's Fund for Innovation in Education. The broad goals of the project are to: 1) create collaborative knowledge-building communities among secondary students, teachers, administrators, university faculty and students, and outside experts, 2) explore the use of networked environments to support collaborative learning; and; 3) model constructivist uses of technology in the classroom.

The project involved the collaboration of an inner city high school (over 80% minority, low SES student population), a suburban high school and a college of education. A unique aspect of the project was the use of students as mentors and a support system for teachers in implementing the new network-based tools for collaborative learning. This presentation provides a summary of the project and the ways that students may serve as a support system for teachers in implementing constructivist uses of technology in the classroom.

2. Network-Based Environments for Collaborative Learning

The project provided participating high school teachers with access, training and technical support related to the following network-based tools and environments to support collaborative learning:

Daedalus is an integrated suite of programs that supports collaborative writing and encompasses all stages of the writing process, from brainstorming and prewriting to drafting and revising to final production.

Team Focus is a collaborative decision-making, consensus building tool developed by organizational management specialists for use in business and high technology settings. Under the direction of a team moderator, participants anonymously enter their remarks in an intense brainstorming session, then group and prioritize the results. Team Focus may then analyze the session results with power graphical and statistical tools.

TeachNet is a BBS environment to support between school and school-university collaboration. TeachNet uses the FirstClass client/server software. It provides a graphic user interface and a number of features to support both asynchronous and synchronous collaborative work among the partner schools. Teachers used TeachNet to share ideas, curriculum materials, discuss problems and issues and to support inter-school collaborative projects. Students established their own bulletin boards based on collaborative projects, as well as issues and topics of interest to them.

Electronic Emissary is a "matching service" that helps teachers locate other Internet account holders who are experts in different disciplines, for the purpose of setting up curriculum-based, electronic exchanges among the experts, students, and teachers. The prototype Emissary program automatically copies, sorts, stores, and forwards project-related messages and generates usage data.

The above software tools and network-based environments were used primarily as scaffolding devices to help teachers move towards constructivist applications of technology and to help them shift their role from that of information dispenser and evaluator to that of facilitator, mentor, knowledge navigator and co-learner with the students.

3. Project Activities

During the initial year of the project, 6 teacher from each high school were recruited to serve as the core CIRCLE team. During the second year the core team was expanded to 12 teachers within each school . The teachers, all volunteers, represented all academic discipline areas. The principal investigators of the project included a university professor, a teacher and a school administrator. Three university graduate student research assistants provided additional training and technical support. Student mentors were a divers group of 9-12th grade students who were selected by teachers based on their interest in technology. The teachers were asked to include both "successful" and "at-risk" students as members of the student mentor teams within each high school.

Formal training sessions were provided to the teachers and students to introduce them to the collaborative software environments and learning models. Formal training for teachers was provided at the university Learning Technology Center (LTC) and informal training and technical support was provided on-site. Teachers received training for each software tool (e.g., Daedalus) that included both the technical and pedagogical issues related to its use. Student mentors received training at the university on the same software application (usually during the week following the teacher training workshop). The student mentor training focused on the technical aspects of setting up and managing the software environments as well as strategies for mentoring teachers and students in the use of the collaborative learning tools. Both the teacher and student mentor training workshops included collaborative and team-building activities as part of the process. Following the training, the student mentors followed up by encouraging the teacher's use of the software tool and offering to set up the software application for the teacher's class and to assist them and the students in the use of the program.

4. Results

The student mentors have effectively served as a support system and a catalyst to get teachers to use the new technological tools within their classes. Many of the teachers reported that, despite what they perceived as very effective training, they still felt insecure in taking that first step in using the technology with their class. There was a lingering fear that they would make a mistake and that it would not work or go well. The student mentors took away much of the risk from the teacher by enthusiastically volunteering to set up the network and or software program for the class activity. The students, demonstrated little fear of failure and persisted until they solved the problem and were able to make the specific computer-based application fully operational. The following are some of the observations and results of the use of student mentors to support the teachers in implementing computer-based tools for collaborative learning:

- a large number of teachers not directly involved in the project have requested that they be assigned a student mentor during the coming academic year
- the student mentor training has now become formalized into a regular class (with academic credit) within the inner city high school
- the use of the high school student mentors has now extended to include the mentoring of middle school teachers and students in technology applications
- teachers and student mentors have both noted positive changes in the role and relationship of student mentors not only with the teachers but with students in the class. Many students who previously had low status within their classes are now recognized and valued for their expertise in the use of the computer tools
- teachers and students from the inner city school reported that the student mentors (from the predominantly Hispanic, low income student population) had few aspirations for higher education before the project, but many have now indicated that they would go on to higher education after completing high school. The teachers indicated that their on-campus experiences as well as in working online with college university faculty and students was an important factor in changing their views toward higher education.

- the use of student mentors has in some instances evolved beyond that of technology-related assistance. Teachers are reporting that student mentors have offered excellent suggestions and ideas for class instructional projects and activities that they helped implement with the teacher.

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Creating the Enriched Case: Using Aesthetics as an Alternative Approach to Designing a Multimedia Case

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Abstract

In this paper we propose that aesthetics provides a useful, efficient approach for thinking about and creating representative scenarios within constructivist case studies. We suggest that complexity, richness and experiential fidelity of the case are functions of aesthetic issues. Our observations draw from the work of Eisner, Dewey, research in graphic design and architecture, our own academic training as artists, and a series of formative studies in which these ideas have been explored within actual instructional situations. Among the issues we have explored are use of the artist's voice, honesty in materials, the understanding of the distinction between medium and tool, and the creation of a unified experience.

Keywords — Case-based instruction, collaboration.

1. Introduction

By their nature, case studies represent an experience through which the learner can study, experiment and discuss a phenomenon without the liabilities of becoming engaged in a problem within an actual environment. Case studies provide students with the opportunity to share and investigate an experience and arrive at rich, meaningful conclusions. However, current approaches to the design of computer-based case studies are frequently inadequate and inconsistent. From a traditional instructional design perspective, the process of preparing a case study is typically defined in terms of specifying objectives, collecting and editing material, and presenting it clearly and unambiguously. We and others have criticized cases built using this approach as not being sufficiently experiential [4, 15, 1, 12]. Case studies created in this fashion focus on allowing the student to extract a message and then apply it to a new situation; the complexity of the case is reduced in order to achieve this goal. The student may assume that all the pieces of the puzzle are present in the case; she has only to fit them together. The great effort that writing a good instructional case study requires is often not repaid in terms of rich, transferable experience.

Constructivists point to case studies as a means of providing an authentic context in which learning tasks may be embedded. However, there is a dearth of literature on how to create these authentic contexts. The Cognition and Technology Group at Vanderbilt state that the facts of a case ought to be embedded within a video narrative [5]. Yet, there is considerable difficulty in applying this guideline within an ill-structured subject domain where the "facts" of a case are unclear. Other researchers suggest that the density and bandwidth of multimedia may be used to represent the messiness and ambiguity of an authentic experience [e.g., 4, 17]. Yet, we question the efficiency of this approach. Designing the case may mean creating vast databases of information; much of the student's time is spent dealing with an inundation of data. Having to deal with masses of uninterpreted data can actually be constricting; one designer was compelled to add video essays to counteract this effect and to provide a "feel" for the location as seen by the filmmaker [13].

We believe that the "richness" and "lifelikeness" , and experiential fidelity of a case have less to do with the amount of information provided and more to do with an aesthetic sensibility [16]. The messiness and complexity of an authentic context may neither sufficiently nor efficiently be represented by great quantities of data in a variety of media, but by the way the creators chose to arrange them. We suggest that aesthetics provides a useful, efficient approach for thinking about and creating representative scenarios within constructivist case studies. Our observations draw from the work of Eisner, Dewey, research in graphic design and architecture, our own academic training as artists, and a series of formative studies in which these ideas have been explored within actual instructional situations.

1.1. Aesthetics and instruction

When we refer to aesthetic strategies, we are referring to practices and ways of thinking inculcated in the fields of art and design. We are referring to the creative and cognitive processes involved in representing experiences within particular media. In cubist painting, for example, the fractured reality represented on the canvas conveys the world perceived from different times and different angles. Yet the artist integrates these perspectives into a unified whole which is representative of the artist's experience. Like a case study, the work refers to a real situation and offers a richness of perspectives. The work is transformed into an efficient, expressive object which creates an experience for a viewer. The artist does not simply create a pointer to the experience. Nor does the artist attempt to reconstitute the whole of reality and then ask the viewer to sort through it.

In our practice, features characteristic of artistic processes offer a useful, efficient framework for developing case studies within instructional situations. In this paper, we concentrate on three of these features:

(1) The voice of the designer is explicitly acknowledged and nurtured.

(2) The computer is seen not only as a tool, but as an expressive and experiential medium.

(3) There is an emphasis on how the separate elements of the case "work" together to produce an integrated experience for the viewer.

2. Myth of the Voiceless Designer

In traditional instructional systems design (ISD), instructional designers typically conceive of a distinction between content and form. Content is seen as something that is instantiated within form. The subject matter expert provides the content and the instructional designer is charged with shaping that content into cohesive instruction. This distinction is a technological one because the designer attempts to use form to accomplish a purpose. Here, form is a kind of tool.

Debates on postmodernism have brought new outlooks to the discussion. One of the earmarks of post modernist perspectives is the inability to see form as something separate from content. But to a certain extent, form *is* a kind of content. There are no value-free, transcendent, transcultural forms within which we can communicate [2]. Instead, a medium, or a form of discourse is always value-laden and biased [3, 14]. The discourse—the form—shapes and informs the content itself. Thus the technological distinction breaks down. Form is no longer a tool, but inextricably linked with content. Eisner observes [9], "the meaning that representation carries is both constrained and made possible by the form of representation we employ. Not everything can be 'said' with anything."

An aesthetic approach contrasts with the technological content/form distinction of traditional ISD in that it sees the designer as having a particular voice in the instructional process. We are indeed co-creators of the content together with the subject matter experts. Therefore, the instructional designer's point of view, philosophy of instruction, outlook on life, sense of style, and personal preferences become a part of the design. The concept of "voice" implies a kind of self-knowledge, a knowledge of the self-in-the-world that informs the instructional design process. In her critique of the influence of post modernism and technology on the practice of graphic design, Wild [19] states that designers must abandon their role as master or expert in favor of that of collaborator, co-author, or participant. She maintains that the most pressing issue in design education today is the development of the young designer's voice and an acknowledgment, therefore, of the designer's more accountable role.

The designer's open acknowledgment of her voice helps face squarely criticisms of post modernism when applied to design tasks. Kampridis, in a re-examination of the meaning of the "postmodern aesthetic" [11] points out, "No single individual has the ability to choose from the totality of traditions as if s/he were equidistant from them....Re-appropriating the contents of traditions entails more than a shopping spree through the malls of cultural history." The tastes and habits of the designer must be made known, and be seen as determining factors–they are not merely conditions of design, they are also among the methods and techniques of design.

Why do we call the notion of voice in design "aesthetic"? Instead of seeing instructional strategies as a collection of tools that the designer applies to learning tasks and situations, the instructional designer must have some sense of his or her "voice" and use the strategies that work most closely in unison with this voice. This is not an attempt to aggrandize the designer; it is more of an acknowledgment of inevitability. The designer is like the painter Dewey [8] describes (p. 87)

> *The painter did not approach the scene with an empty mind, but with a background of experiences long ago funded into capacities and likes, or with a commotion due to more recent experiences. He comes with a mind waiting, patient, willing to be impressed and yet not without bias and tendency in vision. . .The passionateness that marks observation goes with the development of the new form–it is the distinctly esthetic emotion that has been spoken of.*

The first author recently used the notion of voice in the creation of a multimedia simulation of a field trip. Rather than use the multi-vocal approach commonly advocated by constructivists in which various agents express their point of view, a single, first-person point of view was used. We found this rhetorical form more natural to use than a multi-vocal approach. Further, it seemed to us more honest for it dispelled any notion that we were trying to portray a truth outside of our own design. The end result was a compact (for multimedia) 10 MB product. Yet the product enabled students to draw a number of rich, meaningful, personalized interpretations and fed a lively discussion.

3. A view of Computerized Instruction

An aesthetic approach also provides an alternative means of considering computerized instruction. Advocates of constructivism, an instructional philosophy with roots in post modernism, suggest that instructional designers become toolmakers and resource-makers. For instance, Cunningham, Duffy and Knuth [6] have suggested that computers can serve to encourage and stimulate dialogue between students and represent individual and group constructions of knowledge . We agree that these can be meaningful instructional strategies. The aesthetic approach, however, sees the computer as a medium of experience, not simply a tool,. or a means of mediating communication. Dewey [8] made this distinction in *Art as Experience* (p. 84):

> *Science states meanings; art expresses them....The poetic as distinct form the prosaic, esthetic art as distinct from scientific, expression as distinct from statement, does something different from leading to an experience. It constitutes one.*

A computer can seen to embed experience if it is viewed as an aesthetic medium and not a tool. It is the way information is used that creates the experience. In the project mentioned earlier, the point of view expressed in the program did not simply involve portraying the information in text. Rather the point of view was presented in a collage of illustrations, text and sound. The person's intimate reflections were presented in a journal and his feelings about personal issues were conveyed in poetry within a virtual sculpture of a flaming television set. An interactive wisdom "well" portrayed the thoughts and wisdom of the person Although highly abstract at first glance, the set of questions given to the students enabled them to immediately grasp the use of the aesthetic form and proceed quickly through the program. Many commented that they had a sense that this was a real person. One student said that the person seemed so real that she could imagine how he would react in various situations. These are the qualities of lifelikeness, richness and realism we feel are crucial in creating case studies which support long-term engagement.

4. The Aesthetic Concept of Integrity Applied to Instructional Design

The concept of integrity and wholeness, i.e., a sense of fit, appears as a fundamental aesthetic construct in science and in art [18]. Winograd [20] recently remarked, "When a designer says that something 'works'...–it works for people in a context of values and needs, to produce quality results and a satisfying experience." To Dewey [8], an aesthetic experience is "whole, and carries with it is own individualizing quality and self-sufficiency." A product which engenders such an experience exhibits these qualities by the way it is carefully crafted together into an integrated whole in which all the parts work together to provide the desired effect.

The notion of wholeness suggests that a totality of experience be inscribed within an instructional case study. The product serves as a means of defining the negotiation that takes place during the process of its creation. The ability to instantiate the ideas/notions/needs of all of the collaborators in one product/process is indeed an artistic, aesthetic process. The product and process are interrelated and can't be reduced. Thus the process–the design of the designing itself–"says" something, just as the product "says" something; it expresses and states something about the people, the process, and the purpose of the enterprise.

5. Implications

Besides providing a foundation for creating an effective experiential case study, artistic/aesthetic approaches promise an efficient use of instructional resources. The multimedia capabilities of the computer have drawn educators into investigating the creation of virtual reality scenarios, simulated walkthroughs, multimedia databases and other extremely costly projects. The mulitmedia field trip project mentioned above was created by two people over a span of months and was produced by one person within a one month period. Yet the capability of the project for supporting meaningful investigation and its ability to evoke personal responses from its users indicate that we are proceeding in a fruitful direction.

Part of the reason for this efficiency lies in the fact that we do not view ourselves as the sole creators of the case study. Rather, the viewers are the co-creators. In an eloquent article in which he attempts to re-define designing Winograd states [20], "The designer and user are engaged in creating a world, not in simply bringing to the computer what existed outside of it."

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Analysis of Interactions Based on Computer Use from Cognitive and Cultural Perspectives: An Exploratory Study in Mexico

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Abstract

This study presents diagnostic information on Educational Software (ES) in the context of Mexican primary education. It is part of the exploratory phase of a broader study analyzing current computer use and proposing alternative strategies promoting collaborative learning, thinking skills and cultural identity. Due to the limited space of this talk and the lack of basic information on this topic in Mexico, we will only sketch out an overview of the conditions in which computer use and ES take place. Thus, we will not make methodological statements on the way in which the informations was obtained, but we could explain this in the discussion period. The purpose is to give the reader an idea of the beginnings of computer use in the Mexican primary school (specifically, in Puebla) and discuss with our colleagues in order to share our questioning and searches for the development of the broader study.

Keywords — Cultural identity, cultural representations, cognitive, educational computing, primary school, Mexico, classroom interactions.

1. Problem and General Objectives

In Mexico the computer was introduced widely in the primary schools approximately ten years ago, but since there has been no defined educational policy nor any regulations of the use, purchase, and acquisition of systems and software. We could say that the different official programs have been and continue to be experimental in nature. The private schools are in much the same state, where computers are being introduced gradually according to the resources of each school, but without normative or orienting criteria. It might be said that computers in Mexican primary schools are no longer something strange, but neither are they a generalized reality, and that there aare clearly differentiated patterns of use between the public and private schools. And among the latter there is great diversity among the different schools.

The lack of policies, the small amount of research which has been done and the uncritical desire to introduce informations technology in the schools makes it necessary tha both the computer and ES should be incorporated as a way of making children think, allowing them to interact in a collaborative manner without doing damage to our cultural identity and patterns. There is a real danger that the market should determine educational styles, contents, and cultural values. A great amount of the ES sold in Mexico is a simple translation or adaptation of that which is produced in other countries. Moreover, the teachers lack the necessary training to exploit these resources educationally in order to make a critical and creative application in their classrooms, assuming the role of true mediators in this process.

2. Characterization of Public and Private Schools

Our documental and field research allows us to describe the main differences between public and private schools.

2.1. Public schools

This sector attends to the majority of the school population at all educational levels (more than three quarters of Mexican students). In the public primary schools only ES produced in Mexico specifically for this level is used, primarily tutorials which reinforce the required curricula. There is no use of commercial software. In the classroom, the computer is used as a "blackboard", aiding the teacher in the exposition of content; it has a module at the front of the classroom and one computer is used with large groups (30-50 students) in infrequent sessions. Usually there is only one computer per school, and there is not always technical support available in case of problems.

2.2. Private sector

As opposed to the foregoing case, there is no pattern of use or consumption of commercial software, which is the predominant category. The official ES of the public schools is not used, but some schools produce their own. Instruction in computer skills predominaates as an approximations to the use of the computer in education. There is a great variety of levels of availability of equipment, generally much greater than that in the public schools. The groups are small, an the frequency of computer sessions is higher (2 or 4 hours/week). But in many schools the presence of computers is due to a fetish for modernization and as a marketing strategy to attract students. There is too much heterogeneity.

2.3. Most frequent interactions: teacher-computer-group

The analysis of the interactions was carried out in 10 groups at the fourth-grade level in 5 public schools and 5 private ones, selected randomly among those whick use computers as an instructional resource in the city of Puebla. We attempted to find tendencies in schoolroom behavior, during interactions among the teacher, the computer, and the group (of children); above all we tried to show how the differente stages of information processing: entry, elaboration or reasoning, and exit took place. Frome the data obtained from these observations and compiled in a table of frequencies, we conclude the following: In the interaction Teacher-group predominated behavior in which the teacher asked questions to the group, after giving examples, and gave instructions; the explanation of content took place, but not often. Among the group there was and emphasis on asking clarifying questions, in orden to improve their interpretation at the beginning and a little in order to support their reasoning. In the public schools the teacher took the initiative in asking questions, to the point that the group did not ask questions; while in the private schools, the group took the initiative more often to ask questions, and the teacher seldom explain content.

The interaction Group-Computer occurred fairly frequently, but it showed up the substantial difference in the way computers are used between public and private schools. In the public schools, they centered on all the children going at the same pace (with a single computer), while in the private schools each child could progress at his/her own pace, respecting individual cognitive process a little more. The interaction Teacher-Computer was infrequent, generally with the purpose of supporting the process of some child during entry into information. In the private schools this behavior is more marked, and it is used also to favor the reasoning process in itself. Both tendencies are expected, given the number of computers available.

The least frequent interaction was Group-Group or Child-Child(ren); this gives us to suppose that the present modes of computer use do not favor "collaborative learning" experiences and the social construction of knowledge. This is more often the case in the public schools, in which this type of interaction is virtually nonexistent. In the private schools the frequency of this type of interaction is similar to that between the teacher and the group,and shows up as group work or an interchange among children, peer mediation.

In conclusion, in the private schools there is a better balance among the different types of interactions; actions or behaviors are shown which tend to favor better conditions for cognitive development, but we supose that they occur more spontaneously and favor certains experiences of "collaborative learning".

2.4. Perceptions and opinions of the children

In an attempt to find out about the children's perceptions of the computer in relation to their context and cultural practices, we found that children in the public schools perceive it as an educational support which is easy to understand in its language and structure. This is due to the tutorial nature of the official ES and its close ties to the curriculum, as well as the fact that it is in Spanish. In the private schools opinions were more varied, and occasionally the children expressed lack of comprehension of the computer language and the frequent instructions in English.

Almost all the children interviewed (12 in all) both in public and private schools give greater authority and credibility to their parents and teachers than to the computer, since they consider thaat it is a machine and not the same as people. Half of the children said that they did not understand the visual images, nor did they find any similarity between the objects and images on the computer screen and those they see on the television. In general they showed interest and liking for using computer, without showing any marked fascinations with it.

In synthesis, the language and authority represented by the computer would seem, as a working hypothesis, not to have caused any substitution of the cultural patterns of a strong tradition cultures (Bowers, 1988), nor a predominance of the rationalist-Cartesian thinking implicit in the computer. This must be further studied in a broader and more controlled study, keeping in mind the limited access which Mexican schoolchildren still have to the computer.

2.5. On the commercial supply of ES in Mexico

This exploratory study showed the lack of a general catalog showing the ES which comes into the country or is produced there for sale. There is a great dispersion of informations in this respect. Most distributors sell everything from systems to software, and the vast majority do not specialize in ES, still less for the primary level, so that it was difficult to identify the universe of those who produce or distribute for this level. In almost all cases, the personnel are not trained to give information, and there is little or no technical data (type of ES, level, context of use, manual, foreign or national production), nor are there counseling services for acquisition or training of users. The consensus is that parents are the ones who buy most ES, on an intuitive basis or according to price, since they have no criteria or guidance for deciding what to buy, what it contains, what it develops, how and why to use it, etc.

3. Basic Theoretical Support for Computer Use in Education

3.1. Cultural and epistemological implications.

We take as a given the non-neutrality of technology and computer use in education, using as our principal source the work of Bowers (1988) and Flores & Winograd (1986). We claim that the computer is a "cultural mediation" which acts as a vehicle for the ways of thought of the system of ideas, symbols and languages of Western philosophy, based on rational empiricism. ES has an effect on the symbol and value systems of the child. Children do not learn only content, but rather are exposed to the acritical legitimation of a form o thinking and category structures, whether or not they are close to their own cultural context.

It is important to analyze the way in which computers influence the patterns of communication, the structure of knowledge, the mediation between the sensory relationships of the individual with his/her environment, recodifies cultural vocabulary, exercises a selective influence on what is retained and what is lost in the process of transmission. The cultural implications of computers in education acquire a greater relevance in Third World countries because the acultural nature of the rational process, technology and language is assumed. The cultural presuppositions of information technology at a cognitive level and the main points of alert which should be considered are:

(a) A Cartesian focus of Western philosophy which determines the way in which the programmer represents the objects of knowledge and establishes relationships within the subjects.

(b) A rationalist view of information technology, based on the mind's ability to objectivize the external world and see language as a system of symbols organized in patterns which correspond to objects in the real world.

(c) A conception of knowledge as the power of the individual, which is transmitted to the detriment of socially constructed knowledge.

(d) The predominance of rational authority over moral and conceptual authority.

Western thought and its conception of science and technology underestimates all types of conceptual or moral authority except for that based on empirical evidence. But this forms of authority are those which regulate interpersonal relaationships, the relatinoship individual-environment and individual-community. This leads to an underestimation of tradition and intuition as sources of knowledge in favor or innovation and quantification. In Third World countries this can take a turn which abandons history, collective memory and the holistic vision in order to privilege advance planning and isolated temporary facts (Bowers, 1988, p. 124).

3.2. Elements to be considered and integrated for a cognitive approximation

In the first place we begin by considering knowledge as something which is socially constructed, implying processes of cultural mediation, and which therefore requires a cognitive approach from a compatible focus. In this sense we assume the mediating action proposed by Vigotsky's "cultural psychology" (Crook, 1991) to be deposited in the software. Thus his Theory of Social Development of Higher Psychological Processes, his idea of the Proximate Development Area, and instrumental mediation, it offers element to tie together both approaches, since it says that the higher functions and other abilities of cognitive competence have a mediated structure. In the second place, although these concepts allow us to think about the cognitive nature of the problem, since this is centered on the classroom interactions during the use of ES as a unit of analysis, this requires a greater degree of operativity. Therefore we consider it relevant to incorporate R. Feuerstein's proposal on Cognitive Modifiability and Instrumental Enrichment (Beltrán, 1992), particularly in reference to the expression of abilities which are manifested in the stages of entry, elaboration, and exit during the processing of information. In the third place, together with the foregoing, we feel that J. Nava's (1992) proposal is relevant, in the sense that the elementary abilities acquire meaning if they are integrated with commonly-used intellectual processes, as a valuable product and a motivating degree of difficulty, referring to what he considers to be <u>intermediate</u> abilities of interpretation, justification and expression; which in turn can be associated with the aforementioned stages of entry, elaboration and exit. Finally, in order to facilitate the analysis if the interactions understood as the search for intentional processes of cognitive mediation, another focus adopted to schematize it is Bossuet's (1990) proposal, in which the relationships within the triad Teacher (mediator) - Computer (ES) - Group (children). All the preceding was taken into account in the elaboration of the instruments for registering the observations in mexican schools.

4. Questions and Points to be Discussed

(a) Can the differences found between public and private schools be explained as a simple consequence of the difference in resources between the one and the other?

(b) Is it viable for there to be a greater articulations between the cultural and cognitive perspectives, dealt with separately in this first approach? Perhaps establishing a greater convergence with respect to concepts such as criticality, language, mediation processes.

(c) According to Bossuet's proposal on the "computer ball" or that suggested by C. Crook on the limitations in acces to computer technology. Does this ask us or condition us to opt for a pedagogy centered on processes of "collaborative learning"?

(d) A greater congruence with Vygotsky's and others' epistemological principles as to socially constructed knowledge. Would this reduce the risks stated by Bowers in the incorporation of computers in cultural contexts with their own traditions?

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Collaborative Learning as Interplay between Simulation Model Builder and Player

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Abstract

We present a simulation-based learning environment that supports collaborative learning as interplay between a model builder and a player. The SESAM system serves as a medium through which a model-builder and a player communicate understanding and experience about an evolving model.

Keywords — simulation-based learning, model-builder player collaboration, collaborative environment.

1. Introduction

A simulation-based learning environment SESAM (Software Engineering by Simulation of Animated Models) has been developed to investigate software engineering concepts and how to apply these concepts to practical situations. SESAM simulates the development cycle of a software development project, allowing each player to participate in the role of project manager. The system simulates software artifacts, various types of documents, fictitious participants (including client and project members), and the project evolution over time based on a model constructed by a model-builder.

Our approach integrates simulation model-building and playing with a learning environment rather than separating the two activities. Mediated by SESAM, a model builder and a player collaboratively analyze software engineering phenomena by constructing, validating, and refining a model of a software project through a cycle of four processes: (1) a model builder constructs a model; (2) a player interacts with a simulation based on the model; when the player experiences difficulties, he or she annotates simulation runs with textual remarks and questions; (3) the model builder analyzes the recorded simulation run; and (4) the model builder and the player examine the run together. The system's graphical interface allows model builders to construct models via direct-manipulation interaction. A text-based menu-driven interface allows players to interact with the simulation (see Figure 2).

Although we present our work in the domain of software engineering education, we expect the approach and its computational substrate to be applicable to many educational domains in which models are still evolving.

2. The Model Builder and Player Approach for Simulation-Based Learning Environments

Models are formal representations that highlight specific aspects of a much larger and more complex problem. Models omit details not relevant to the current task and help people focus on problems at hand in "practical" situations.

Most simulation-based educational systems [4, 9] do not support the evolution and refinement of underlying simulation models. Many systems are based on the assumption that an appropriate model already exists in the domain. Consequently, such systems completely separate model building activities from simulation-playing activities.

In rapidly changing work domains, however, the underlying model easily becomes obsolete. In domains such as software engineering, for instance, building a simulation model itself is a research activity. There is little qualitative information available that is precise and unambiguous enough to base a model on. Models, rules – any explicit representations can never completely cover reality [10]; some parts of current affairs always remain tacit [6]. In these domains, not only students, but the model-builders themselves need to learn about the domain by refining the model.

To cope with this problem, a simulation-based learning environment needs to support collaborative learning as the interplay between a model builder and a player. This changes the view of collaborative learning from the teacher-student relationship to the model builder-player relationship. As illustrated in Figure 1, a model builder and a player interact through a simulation-based collaborative learning environment.

The simulation presents the consequences of the player's interaction based on an underlying model. The player may make questionable decisions, or make mistakes that are anticipated by the model, which lead to consequential problems within the game. Making mistakes is a great opportunity for a player to learn. Explanations and information relevant to the problem can be provided, being contextualized within the simulated situation that the player is directly engaged in [2]. At the same time, it is possible that a player's actions reveal a deficiency in the underlying model, which leads to implausible model behavior. Such breakdown situations provide a model builder with opportunities to analyze and refine the model by exposing tacit aspects of practice. Thus, the model builder also learns.

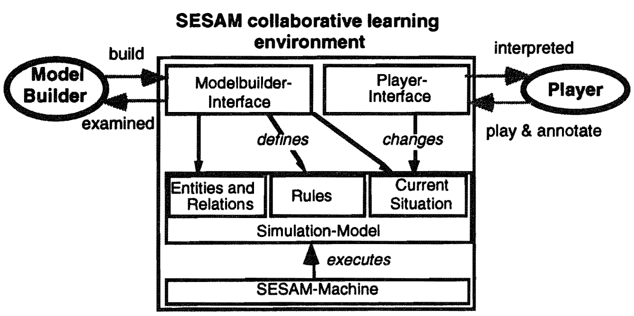

Figure 1. Collaborative Learning between a Model Builder and a Player through SESAM.

Figure 1 illustrates the SESAM architecture. The *SESAM Machine* interprets graphical models, produces textual simulation runs, automatically proceeds model time, applies effect models whenever appropriate, keeps track of model evolution and triggers pseudo-random events.

3. SESAM

SESAM was developed at the University of Stuttgart (Germany) as a tool for software engineering research and education. The system is written in Smalltalk 4.1 and runs on several different platforms.

A SESAM player manages a project by planning the project, updating those plans, and then enacting the plans in fine-grained daily decisions. As project manager, players act on and react to changing situations represented by fictitious artifacts and stakeholders (clients and project members). Project evolution is modeled based on the software quantum metaphor [1, 7], which models functional completeness of software artifacts and documents quantitatively. Pre-stored statements from fictitious team members are triggered and displayed according to the project state and player's interaction. The goal of the player is *"to produce required functionality and quality within the budget and schedule by motivating team members, by assigning them to adequate tasks, and by involving the client to validate the evolving requirements."* In what follows, we present a scenario to describe how a player interacts with the system through the player interface, followed by a brief overview of the model builder interface. See [3, 7, 8] for details.

3.1. Scenario

When Jane, a computer science student, first invokes SESAM, a short project description is presented in the *What Happened* window (see Figure 2-(a)). Although the given deadline and budget partially indicate how to plan her project, she lacks important details to estimate her project's effort. She has to take some actions using the *Simulator* window.

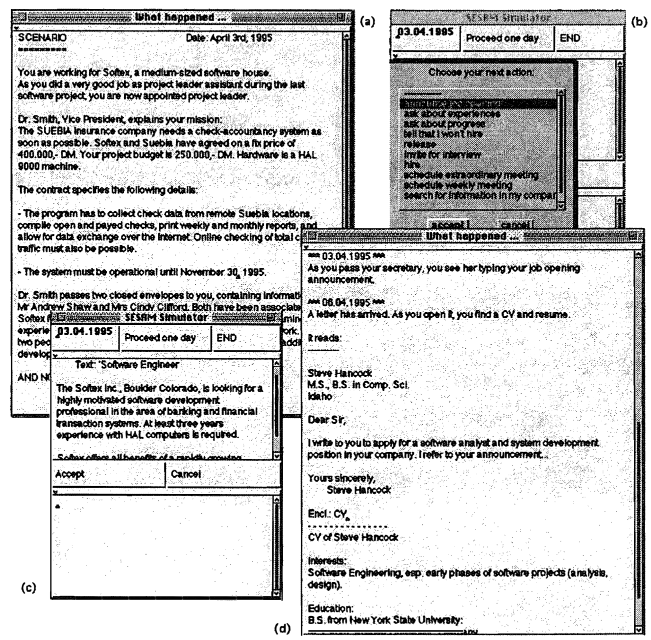

Figure 2. Screen Images of SESAM.

Jane finds a long menu of possible actions (see Figure 2-(b)). Some of them (e.g. "finish project") are obviously inadequate. Jane first wants to hire team members. She selects the *"announce job opening"* entry, and the system asks her to specify the exact text of her job opening (see Figure 2-(c)).

After she completes the job-opening specification, SESAM executes the simulation according to her action. At first nothing happens. Jane notices that the model date (see the upper left corner of the *Simulator* window in Figure 2-(c)) has been incremented by one working day. Writing the job opening costs her one day. Jane takes several more actions; she introduces herself to the customer, plans and looks for information in the company. Some simulated days later (some minutes later in real time), a resume and CV appears on the screen. *Steve Hancock* applies for the job (see Figure 2-(d)). Jane invites Steve for a job interview and decides to hire him. Like all other actions, job interviews and hiring a developer take model time.

Later in the project, Jane finds herself left alone with very little feedback from Steve and the other team members she hired. In meetings, she gets only superficial pieces of information on project progress (e.g., "We *have about 10,000 lines of code*"). Jane gets frustrated and complains about this in an annotation: "*How can I estimate cost and effort, if I have no precise status information?" "What is the quality of my product?* " and *"What does it mean to have 10,000 loc?"* Desperate, she invites the customer for a prototype review. To her surprise, the customer is not satisfied and requests several modifications. Now, all of Jane's plans must be updated, all documents (specification, design, code) must be reworked. Soon it becomes clear that the customer is good at finding flaws. At some point, however, Jane must decide to nevertheless continue development; otherwise she will risk schedule and budget slippage.

After Jane finishes her simulation game, Jane's advisor, Bill, reviews Jane's simulation. Because of her annotation, Bill finds that Jane was frustrated by the sparing feedback from her team members. Bill also finds that Jane's idea of inviting the customer was a good action, as it allowed Jane to assess product quality. Bill explains to Jane that in reality, no one tells project managers about their product quality, either. Jane and Bill talk about quality assessment techniques that Jane could have used. Jane claims a real software developer would have given at least some hint of the degree of work completion; the fictitious team member Steve did not. Bill agrees with her comment and considers model extensions.

3.2. Model Builder Interface

The system uses three types of representations for a simulation-model: entity-relationship model, rules, and particular situations. The model builder interface provides three semi-graphical editors accordingly. Building models does not require any significant programming.
The *Entity-Relationship (ER) model* schema (see Figure 3-(a)) defines entities and relationships that constitute the model world. In the *situation model,* the initial setup for the simulation is created by instantiating the entity types (see Figure 3-(b)). A textual description of this situation represents th context to the player. *Effect model (rules)* are used t describe dynamic behavior of simulated projec participants, evolution of documents and artifacts (nc shown).

4. Discussions

SESAM allows both model builders and players to ti their experiences and arguments to a common medium: the model and its simulated events. To foster this collaboration both in indirect (asynchronous) and face-to-face (synchronous) modes, the system keeps a record of player actions together with model time stamps to trace what has happened during the simulation. The accumulated data (player actions, invisible model behavior, and final project results) is a basis for discussing a simulation run in detail. When a run is reproduced based on the interaction protocol, additional information can be captured and displayed, including attribute value plots, effect model activation and deactivation information. Model builder and player may also make modifications to the model and rerun it on the fly to see the consequences.

SESAM mediates collaboration by making models accessible from two different perspectives: (1) a model builder initially accesses phenomena through the semi-graphical model notation, and (2) a player refers to textually represented events that occurred during the game. The model notations used in SESAM are a graphical, though *formal* representation of a project

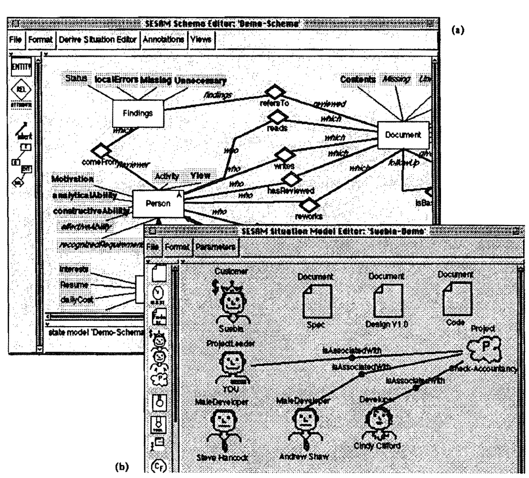

Figure 3. ER schema (a) and a situation graph (b) of a model used in the scenario.

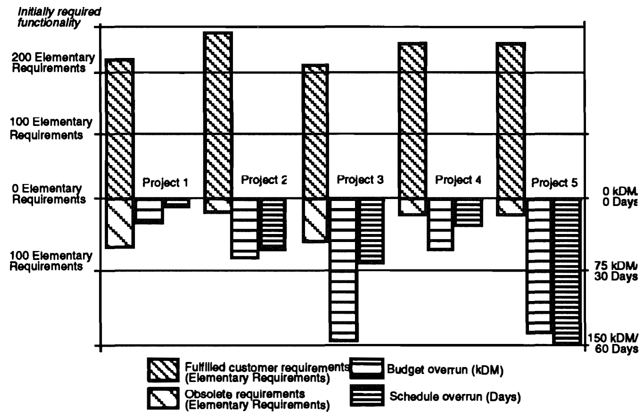

Figure 4. Overall results of the project management course.

model. *Informal* annotation is provided to complement those formal model aspects to provide expressiveness to players. Mediated by SESAM, model builders and players discuss questions such as "*does this effect really occur in software projects?*" "*what are the reasons, and how are they represented in the model?*" and "*why is it important to know this effect and to integrate it in an educational model?*"

A study of SESAM with a graduate level course at the University of Stuttgart has demonstrated that the approach was effective both for students (served as players) and for faculties (served as model builders). In the study, the model used in the above scenario was presented as an adventure game to 10 graduate students of computer science in a project management course. All students were asked to play the same simulated project in independent, parallel games. As illustrated in Figure 4, results differed dramatically in terms of quality and resource consumption due to different management. Project distortions were tracked back to early planning or scheduling mistakes. The project which performed best (Project 2) had a project plan which was constantly updated. Project 3 performed worst; it spent a lot of effort unsystematically, which resulted in large overrun on budget and the worst quality delivered. For detailed description of the model and the course, see [1].

The upper part of Figure 4 represents functional completeness, which should be as high as possible. The lower part gives the amount of obsolete functionality, the budget overrun in 1000 DM, and the schedule overrun in days, the values of which should be as low as possible.

5. Conclusion

We view learning as collaboration between a model builder and a player mediated by computational environments. Software engineering knowledge is scattered. There is no concise, comprehensive model that is accepted by a wide range of researchers and practitioners. Software engineering textbooks convey isolated, mostly vague pieces of advice, due to the general scope and audience they are written for.

Traditional instructionist knowledge transfer approach is inadequate for such educational domains [5]. SESAM provides two perspectives on a single evolving model. The model builder perspective offers semi-graphical interfaces for constructing a model to be used for simulation. Players experience the model's dynamic behavior in an adventure-game style through the player perspective. The system records the simulation runs, and players can annotate the simulation with critiques and questions. Our assessment studies have demonstrated that relatively simple models provided opportunities to learn for both model builders and players – in both reflective and experiential modes.

Acknowledgments

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Collaborative Writing Software for Problem Solving in Math

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Abstract

Although many different forms of collaborative writing exist, the definition proposed is any procedure whereby two pedagogical assumptions are met: (1) writing helps students discover their thinking process, and (2) sharing critical thinking methods can show students the divergent ways people find solutions. Computers are useful in collaborative writing because repeated use of tutorials can help students learn problem-solving methods, allow students to share their work in a flexible manner suited to many classroom environments (K-12 and college), and serve to give teachers a window into the thinking process of their students. The SEENMath software, developed through a National Science Foundation (NSF) grant, comes with a tutorial in mathematical problem-solving (based on Polya's four-step heuristic) that allows students to accompany their writing with drawings, calculations or graphs. Students share their completed explorations of a problem with other students through a built-in bulletin board that allows peer review. Use of the software at Indiana University-Purdue University, Indianapolis (IUPUI) with large sections of Finite Mathematics shows the practicality of including collaboration as homework (for predominantly non-science majors) via a computer program at a commuter campus.

Keywords — math, problem-solving, writing, commuters, non-science majors.

1. Introduction

Mathematics educators, through the National Council of Teachers of Mathematics' STANDARDS, have called for more active learning at all levels of mathematics education. Students especially have problems with "word problems." Our project is to encourage active learning by modifying the structure of SEEN (an award-winning humanities software program). The initial tutorial models Polya's four-step problem-solving heuristic: understanding the problem, devising a plan, carrying out the plan, and looking back to evaluate and apply. However, SEEN-Math also allows an instructor to revise an existing tutorial or create a new one.

The new software, SEEN-Math, is being implemented in a Finite Mathematics course at Indiana University-Purdue University at Indianapolis (IUPUI), an urban commuter university in which most sections of the class are large, most students are non-science majors (primarily Liberal Arts, Education or Business), and student collaboration outside class is difficult to arrange. SEEN-Math is being introduced at IUPUI to promote learning through writing and collaboration in a way that fits the logistics of an urban commuter university. It is being assessed on the basis of student use and outcomes. In addition, SEEN-Math is being incorporated into the methods courses for elementary education and secondary mathematics education majors, because the student work recorded in SEEN-Math provides a window on the thinking process of novice learners.

2. Basis in Learning Strategies

The use of writing in assignments throughout the curriculum has been growing based on research-based recommendations and assumptions (first published on a large-scale study of British schools by Britten et al.): that writing is important not only for communication but also for the discovery of ideas and a holistic understanding of a subject. The inclusion of collaborative activities grows from educational theory that group work necessarily involves the articulation of goals as well as ideas--and that these metacognitive activities improve learning and retention (Hillocks; Bruffee).

Computer-based materials can employ these strategies, making classrooms and homework assignments more flexible in scheduling. SEEN (designated as EDUCOM./NCRIPTAL Distinguished Software in 1985) has always included tutorials that present open-ended but structured questions for discovery learning and a built-in bulletin board that aids peer review.

The program is based on the following assumptions about learning:

(1) Informal writing engages students with material and leads to the discovery of new ideas.

(2) Seeing the work of peers helps students see different points of view (and the need for supporting evidence for their ideas) and compare their own work to that of others.

(3) Participation in peer review and revision gives students experience in evolving knowledge in contrast to the idea of knowledge as memorizing truth.

(4) Repetition of tutorial questions (such as sets of questions--or "heuristics"--that lead a student through character analysis in literature) helps students internalize those heuristics.

(5) A teacher who reads student output gains a window into the thinking process of students and thereby gains a better idea of what students need for guidance.

The humanities tutorials, without multi-media utilities, have been described as helping students internalize heuristics (Schwartz), as providing feedback with which students can revise papers (Hastings) and as involving students with their evolving ideas more effectively than paper-and-pencil responses (Schwartz, Fitzpatrick and Huot).

3. An Illustrative Example

In Spring 1995, students have used SEEN-Math in conjunction with a large lecture section of Finite Math along with a standard textbook. In addition, they work three special problem sets using SEEN-Math. Going to any campus computer lab during free time, a student calls up SEEN-Math from the campus network. She enters her name and id number (so that her activities can be noted by the administrative part of the software). Then she is ready for the questions (with questions and answers shown in the sample included below).

Help is available from two sources to the student as she proceeds. First, an example of a completed tutorial is available from any screen on the tutorial. Second, each question has an associated advice text that gives an example for answering that question or gives further explanation.

The network management utilities make sure that students get the tutorials and groups they have been assigned, make note of the activities they perform, and store copies of work posted on the bulletin board. The authoring utility allows the writing of completely new tutorials or revision of the questions, advice and example in existing tutorials.

4. An Actual Example

This section shows, first, the problem students were asked to solve with the SEEN-Math tutorial questions and then a sample student response:

> A study of 150 high school juniors was conducted to determine the use of alcohol and cannabis. The term "use" is defined as at least once a month. The results of this study were published through the following statements. How many females use either alcohol or cannabis?
>
> 52 males were in the study
> 37 students use cannabis
> 77 students use alcohol
> 21 males do not use either alcohol or cannabis
> 0 females use alcohol and cannabis
> 10 males use alcohol and cannabis

Here is an actual response provided by a student in one section of Math 118 (with SEEN Math questions in boldface):

<u>**Understanding the Problem**</u>

Identify the source of your problem so others can find the original wording:

Watt, supplementary question #2 to chapter 1

State the problem in your own words.

A group of males and females who use booze and pot. Some males use neither, some use one or the other, some use both. However, no girl uses both.

What are you trying to find?

How many females use either alcohol or cannabis.

What are the data that might be useful to find the unknown: How many females use either alcohol or cannabis?

150 students
52 M, 37C, 77A
21 M don't use either
0 F use both
10 M use both

Find the connection between the data and the unknown. List any equations, facts or formulas you might use to find the unknown: How many females use either alcohol or cannabis? For ADVICE, click on the ADVICE button.

Males are complement of females.

__Devising a Plan__

Can you think of a problem similar to this that you have seen before?

[If the students says no, s/he is taken to the next new question. If s/he clicks on "yes," she is asked to answer the following question: **Describe the similar problem and what you remember about the method that solved that problem.**

> In the text p. 26, #12. Students were grouped into 3 subsets: domestic, import, or bicycle. With Dom and Impt cars being mutually exclusive (0). The key was not to overlap the two types of cars. I am not sure if it was even possible to solve for all of the partitions in the Venn diagram.

How are the data and the unknown (How many females use either alcohol or cannabis) related in your problem? (You may want to back up to review the data you thought would be helpful. use the Previous and Next arrows to go back and forth in the tutorial.)

> [student did not answer this]

Put into your own words the essential steps and methods of your plan to solve the problem and state why these methods should produce the solution to the problem.

> Draw a Venn Diagram.
> Be careful not to overlap sets for females.
> Calculate the numbers for as many partitions as possible
> Shade the areas that add up for the solution (that is, labem them x and y).
> Add up the numbers to the areas for females that use either.

__Carrying Out the Plan__

[The student carried out the plan by using the Paint program to draw the Venn diagram, which was then pasted into the text of the tutorial, as shown in Figure 1.]

Your plan was to solve for the unknown: How many females use either alcohol or cannabis. Now that you have carried out your plan, what solution did you find?

> x + y = 73

__Looking Back__

Does your result, x + y = 73, make sense to you?

[If the student clicks on "yes" (as in our example), the student is taken to the next question below. If the student clicks on "no," s/he is told, "Describe why your solution (x + y = 73) does not make sense to you." and then is given the chance to go back to review his/her plan.]

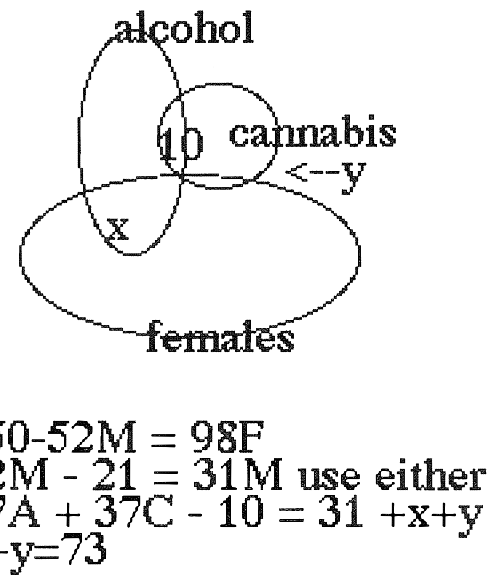

Figure 1. Venn diagram.

How would you describe your feelings and thoughts about this problem--for example, to a friend?

> I still don't know why on these problems I can't get numbers for all the particitions. etc. Why did I not use the fact that there were 98 females?

Describe how you can use this result or method to solve other problems. For example, write a related problem of your own that would use this same plan. (Use the ADVICE button to get an example)

> A survey is taken before the debates. Each person was asked who they would still consider voting for (none, one, or more than one) Perot, Bush, Clinton. No person who was considering Perot was still considering Bush.

5. Elements of Tutorials

Tutorials are constructed from 3 kinds of screens and several strategies for presenting material. Possible screens include information screens (which call for no response), limited-response questions (which require answers limited to about 100 characters so that they can be embedded in subsequent questions) and open-response questions (which accept virtually unrestricted imput). In addition, a pseudo-branch can be arranged by preceding a question with a yes/no question (for example, if the user says "no" to the question, "Can you think of a similar problem?" the question about similar problems is skipped). A yes/no question also allows the repetition of a question to which there may be more than one answer. Finally, a feature of the authoring program allows the input of one screen to be brought forward to another screen as a prompt; in effect, this strategy allows complex thinking processes to be divided into parts. For example, when asking for a comparison and a contrast, one question can ask 'in what ways are X and Y similar?' Then on the next screen, the output appears, followed by the word BUT, and the question prompts the student further: 'In what ways are X and Y different?'

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Comparing Constructions through the Web

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Abstract

Much of the richness of a collaborative learning environment comes from the differing constructions that different learners bring to the learning domain. However, the differences in terminology and its usage that stem from different construct systems can also be major impediments to collaboration. Techniques from personal construct psychology may be used to make such tacit differences overt and a source of rich discussion among collaborative learners. This article describes the use of construct elicitation, modeling and comparison services on the World-Wide Web to enable collaborative learners to understand one another's constructs.

Keywords — Personal construct psychology, repertory grids, World-Wide Web, collaborative learning.

1. Introduction

Personal construct psychology (PCP) [1] emphasizes the idiographic nature of individual constructions of the world and hence raises questions about the basis of inter-personal collaboration and shared, social constructions [2]. PCP has been used extensively in both studying and supporting learning processes [3-6], and computer-based tools have been developed to elicit, model and compare construction systems [7-9]. Such tools running on personal computers have been used to support collaborative learning [6], and the tools have been extended to support collaborative elicitation and analysis over local area networks [10, 11].

Tools for eliciting and comparing construction systems could become a truly *emancipatory technology* [12] for collaborative learning, if they were widely available over the Internet. This article describes the operation of such tools as part of the World-Wide Web, and illustrates their application to collaborative learning.

2. Construct Elicitation and Modeling

The major methodology that we have used for the elicitation of constructs and terminology from individuals and groups is based on extensions of the *repertory grid* technique originally proposed by Kelly [1] as an empirical measurement methodology appropriate to personal construct psychology. Repertory grid techniques elicit knowledge indirectly by prompting individuals for critical elements and relevant constructs in a coherent sub-domain. The techniques are difficult to undertake manually as they require feedback and management from the elicitor while at the same time attempting to avoid inter-personal interactions that would distort the elicitee's construct structures. Hence the advent of the personal computer in the mid-1970s and its evolution into the graphic workstations of the 1980s has made the computer implementation of interactive repertory grid elicitation an attractive area of development [7, 13, 14].

The repertory grid methodology gives a basis for approximating intensional distinctions, or *constructs*, through their extensions when applied to elements in a domain. The distinctions made by two individuals can then be compared in terms of the differences in their extensions and in the terminology used. The two relations of similarity between distinctions and between terminology give rise to a 4-way classification of constructs [8, 15] as shown in Figure 1.

		Terminology: Same	Terminology: Different
Distinctions	Same	***Consensus*** Individuals use terminology and distinctions in the same way	***Correspondence*** Individuals use different terminology for the same distinctions
Distinctions	Different	***Conflict*** Individuals use same terminology for different distinctions	***Contrast*** Individuals differ in terminology and distinctions

Figure 1. Four-way comparison of constructs in terms of the distinctions made and the terminology used for them.

Consensus arises if the construct systems assign the same term to the same distinction. *Conflict* arises if the systems assign the same term to different distinctions. *Correspondence* arises if the conceptual assign different terms to the same distinction. *Contrast* arises if the systems assign different terms to different distinctions. The usual technique for eliciting these comparisons is to have two people negotiate a common set of elements characterizing a domain, each separately develop their personal constructs based on these elements, and then exchange their grids with the ratings removed and attempt to rate the elements on the other's constructs. The comparison of the exchanged grids allows consensus and conflict be modeled, while that of the original grids allows correspondence and contrast to be modeled.

3. Computer Supported Modeling of Construction Systems

RepGrid [16] is a computer-based tool providing an integrated set of tools for elicitation and analysis of elements and constructs in a given domain. It combines a number of different techniques, for construct elicitation, modeling, and comparison. The main tools in RepGrid are:

- *Elicitation tools* which accept specifications of elements within a domain and provide an interactive graphical elicitation environment within which a person can distinguish elements to derive his or her constructs within the domain. The resultant construct system is continuously analyzed to provide feedback prompting the person to enter further elements and constructs.
- *Modeling tools* use various forms of clustering and entailment derivation for the analysis and display of the construct systems elicited: FOCUS shows the system as a hierarchical structure; and PrinCom as a spatial map.
- *Exchange tools* extend the elicitation tools to share elements and constructs between people and allow the terms in the construct system derived from one person to be used by another in order to determine whether the two construct systems are different in any way. It can also be used by the same person looking at changes in their own construct structures over time, for example: after reading a specific book, or exploring a particular domain.
- *Comparison tools* process results from several people to reveal the similarities and differences in their construct systems, or the same person at different times, construing a domain defined through common elements or constructs. It can be used to focus discussion among people on the differences which require resolution, enabling them to classify the disparities in terms of differing terminologies, levels of abstraction, disagreements, misunderstandings, and so on.

WebGrid is a port of RepGrid to operate as a service over World-Wide Web (WWW). Part of its functionality is an interface to RepGrid through the HTTP common gateway interface to MacHTTP. Other significant parts are a dialog generator that replaces the graphic user interface to RepGrid on personal computers with dynamically generated HTML forms accessible through WWW browsers, and a high-speed PICT-to-GIF converter that supports the transmission across the web of the graphic output from RepGrid analyses.

WebGrid is being used to support collaborative learning activities in undergraduate and graduate courses at the University of Calgary. The following sections illustrate its application and show the way in which the personal construct systems of learners may be elicited, modeled and compared through computer-based tools.

4. WebGrid in Action

Figure 2 shows the supervisor of an MSc student using WebGrid through Netscape to start a repertory grid elicitation in the research domain of his student, "learning," that is specifically concerned with the supervisor's and student's understanding of "instructable systems." The supervisor has entered a list of 9 elements, in this case concrete examples of instructable systems, on which to base the elicitation of the way in which he construes them.

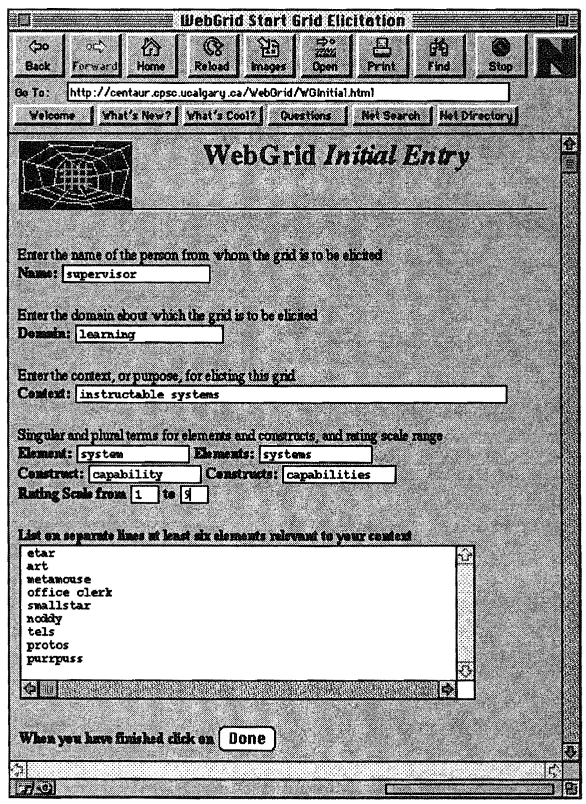

Figure 2. WebGrid initial entry screen.

When the supervisor has entered the data shown in Figure 2, he clicks on "Done" and WebGrid generates the screen in Figure 3 where he is asked to distinguish three of his elements using the standard RepGrid triadic construct elicitation methodology.

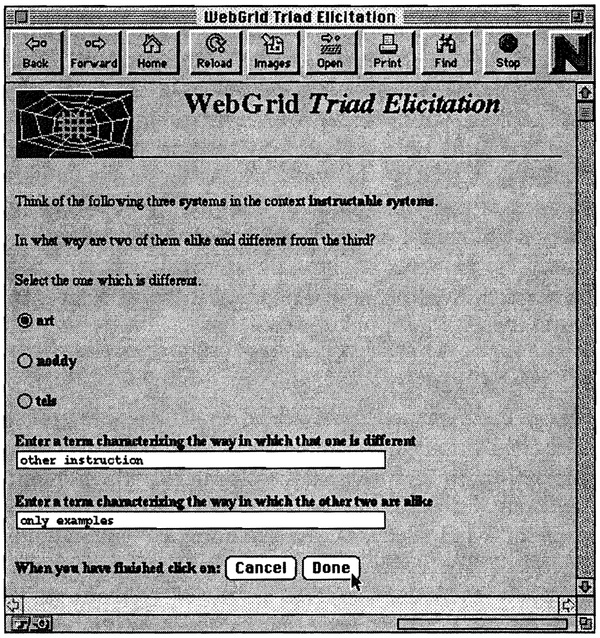

Figure 3. WebGrid elicitation of a construct from a triad of elements.

He clicks on "Done" and WebGrid generates HTML for the screen in Figure 4 where the elements are shown alongside popup menus which can be used to rate them on the new construct as shown in Figure 5.

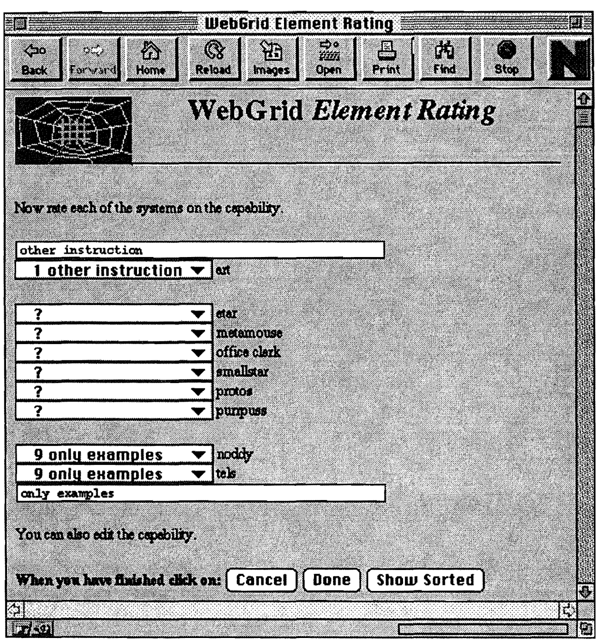

Figure 4. WebGrid rating of elements on a new construct.

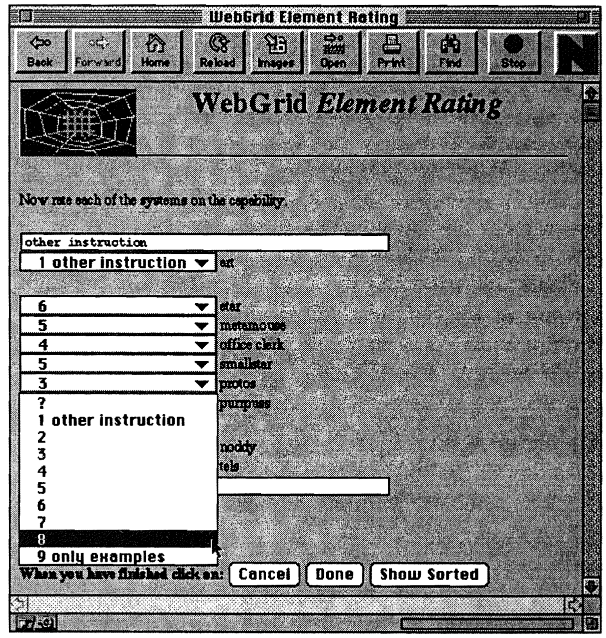

Figure 5. WebGrid rating of elements on a new construct—popup menu scales.

When the supervisor has rated each element on the new construct, he clicks on "Done" and WebGrid generates HTML for the screen shown in Figure 6 which shows the elements and constructs entered so far, and the various options available to the user. These allow the grid to be examined, edited, analyzed, and so on.

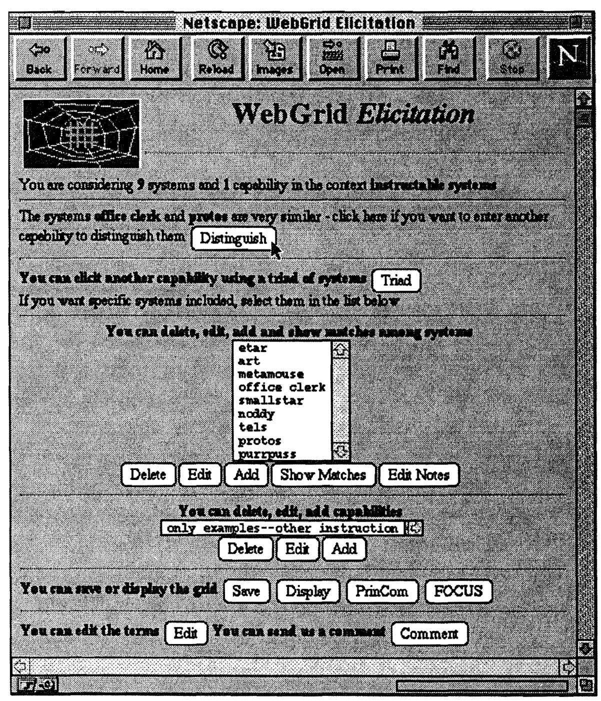

Figure 6. WebGrid main display of elements, constructs and functionality.

This main screen is generated in sections, each of which give the user different information relevant to the elicitation. For example, the first suggestion is that a new construct be added to distinguish between the elements, "office clerk" and "protos." If the user clicks on "Distinguish" WebGrid will generate HTML for a screen to enter a construct with "office clerk" at one pole and "protos" at the other. When the construct has been entered and the user clicks on "Done", WebGrid will generate a screen for rating all the new elements on the new construct similar to that of Figure 4.

Figure 7 shows the main screen when the user has entered 9 constructs. Now construct matches are apparent, and the option at the top of the screen is to enter a new element to break the match between the constructs "weak sequentiality—strong sequentiality" and "non procedural—procedural."

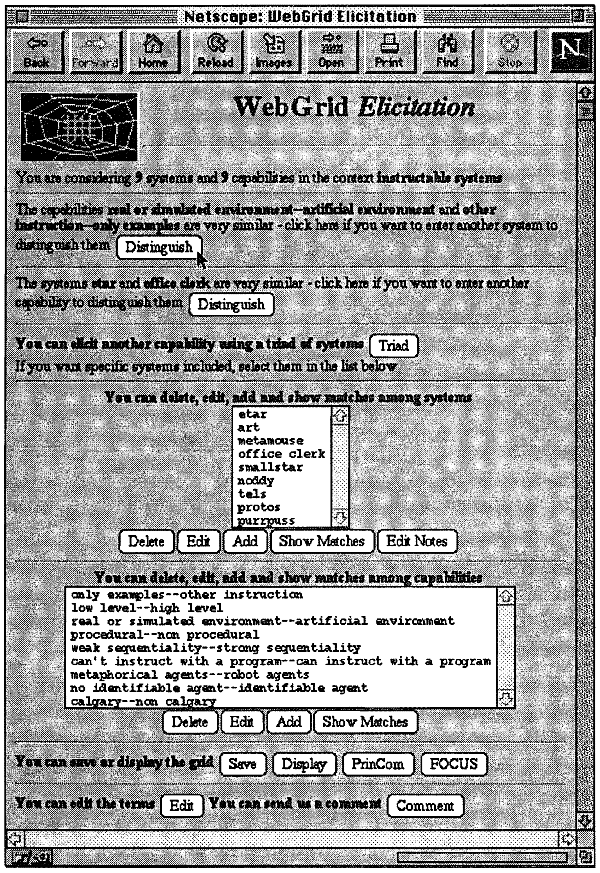

Figure 7. WebGrid continuing display of elements, constructs and functionality.

If the user clicks on "Distinguish" WebGrid generates HTML for the screen shown in Figure 8 where the user is explicitly asked to add one or more new elements that are either "weak sequentiality" and "procedural", or "strong sequentiality" and "non procedural." Thus WebGrid guides the elicitation through feedback about relevant actions that the user may take, but the system is strongly non-modal in that no particular action is forced upon the user.

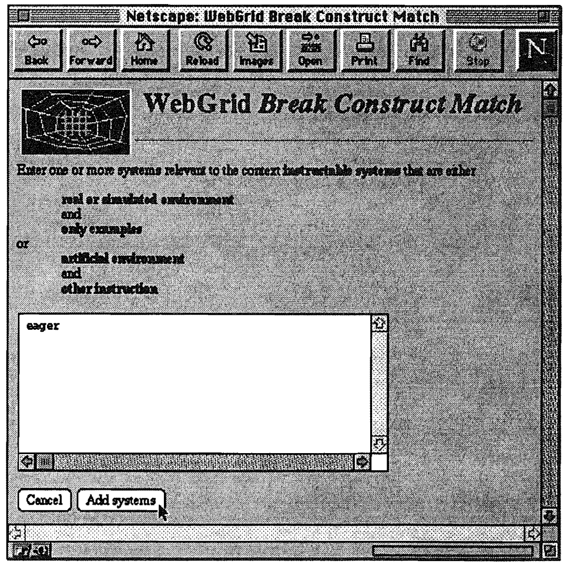

Figure 8. WebGrid entering a new element to break a construct match.

Many other options are also offered in Figure 7. The elements and constructs are shown in sub-windows where one or more may be selected by clicking upon them, and the user may chose to delete, edit or add elements and constructs, or display the matches between them. The user may also choose to display the grid or develop a model of the relations between elements and constructs using the PrinCom or FOCUS clustering techniques. Both of these generate a colored graphical presentation of the results, and WebGrid converts this to the CompuServe GIF format and sends it back to the browser for display as shown in Figures 9 and 10.

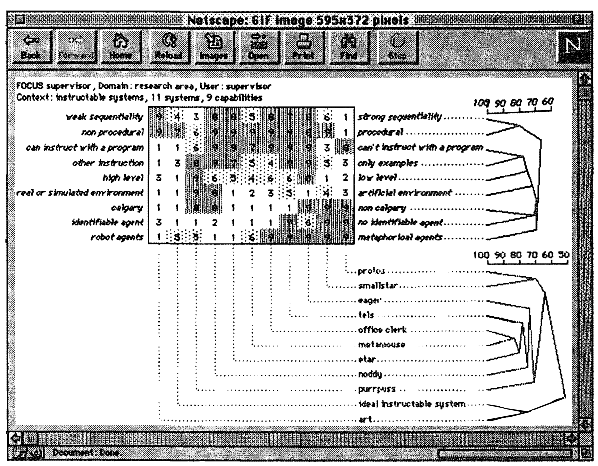

Figure 9. WebGrid FOCUS cluster analysis.

FOCUS sorts the grid for proximity between similar elements and similar constructs. From Figure 9 it can be seen that the constructs "weak sequentiality—strong sequentiality" and "non procedural—procedural" are seen as related, as are the elements "office clerk" and "metamouse."

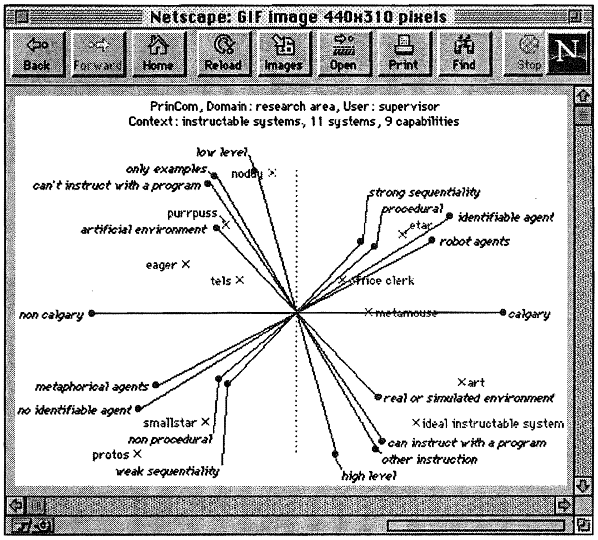

Figure 10. WebGrid PrinCom principal components analysis.

PrinCom uses principal component analysis to represent the grid in minimum dimensions. From Figure 10 it can be seen that there are two clusters of related constructs typified by "low level—high level" and "procedural—non procedural" respectively, plus an isolated construct "calgary—non calgary" raising the issue that Calgary work is seen to be "procedural" and "high level."

The user may also choose to save the grid locally on the client machine. Since the protocol is stateless, and all the grid data is stored in hidden input fields in the HTML form, this is simply a matter of saving the HTML source at the local machine. WebGrid includes the server url in the HTML form so that the file saved may be reloaded at any time and the interaction continued without the need to take special action at either client or server.

5. WebGrid in Collaborative Learning

The examples given have illustrated WebGrid in use by an individual developing a personal model of a domain. This is a useful exercise in individual learning that readily extends to groups since RepGrid has techniques for the comparison of construct systems enabling collaborative learners to explore similarities and differences in the way they construe a domain.

WebGrid allows a user to commence an elicitation based on another person's grid, either using just the elements in it and developing his or her own constructs, or using both elements and constructs but commencing with all the rating unknown (an "exchange" grid). In the first case the new grid may be compared with the original one to determine what constructs correspond in the two grids—the users may be making the same distinctions but giving them different names. In the second case the new grid may be compared with the original one to determine to what extent the ratings correspond in the two grids—the users may be making different distinctions but giving them the same names. When an elicitation is based on an existing grid an additional analysis button appears in the screens of Figures 6 and 7, "Compare."

The example given so far is taken from a graduate class which encouraged students to clarify their interactions with their supervisors, committees and other students in related areas. A graduate student of the supervisor who developed the grid above used the elements in this grid to develop his own constructs. Figure 11 shows the graph returned by WebGrid when the student clicks on "Compare" after having added one construct.

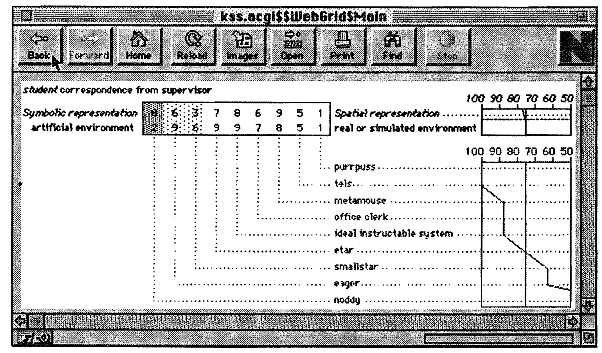

Figure 11. WebGrid correspondence in supervisor's constructs to student's first construct.

The RepGrid analysis selects the supervisor's construct that most closely matches that of the student and displays it below that of the student, adding graphs of the matches between constructs and elements. The student can see that when he makes the distinction "symbolic representation—spatial representation" the supervisor has available a closely related distinction that he terms "artificial environment—real or simulated environment." This raises questions about the nature of the match: is it just differing terminology; is it differing levels of abstraction; is it a causal link; is it a correlated effect in the data?

Figure 12 shows the WebGrid comparison of the student's completed grid with that of his supervisor. For each construct in the student's grid the analysis has selected that in the supervisor's grid that makes a similar distinction among the elements, regardless of what that construct is called. Thus the student's construct "branch conditional on data—choose action based on past state" is shown as corresponding to the supervisor's construct "strong sequentiality—weak sequentiality." In this case the student's construct is concrete and operational whereas the supervisor's is abstract, and they may both gain by understanding and discussing the difference in terminology and the basis for it. An analysis such as that of Figure 12 may often lead to prolonged discussion over a period and to new research insights or the resolution of disagreement—the foundations of collaborative learning.

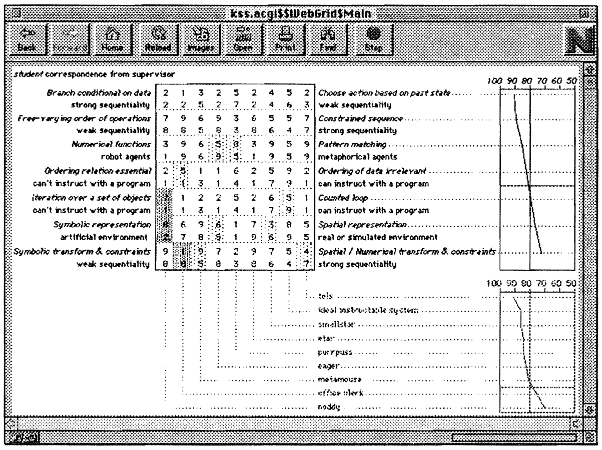

Figure 12. WebGrid correspondence in supervisor's constructs to all student's constructs.

After having developed his own grid, the student also used WebGrid in exchange mode to rate all the elements on his supervisor's constructs. Figure 13 shows the comparison of the student's ratings of the elements on the constructs entered by his supervisor. This analysis allows them to determine to what extent they agree in the use of the same terminology in their research. It is apparent, for example, that they do not agree on the use of the construct "can't instruct with a program—can instruct with a program" or on the characterization of the instructable system "purrpuss."

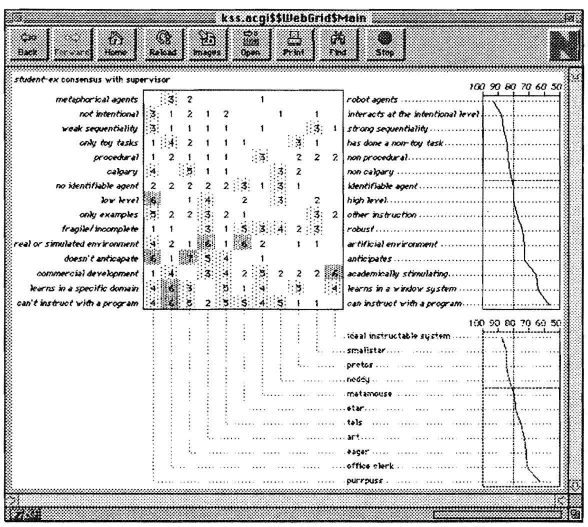

Figure 13. WebGrid consensus between student and supervisor ratings.

Note that the supervisor and student undertook all these activities reciprocally, each developing their own grids for the domain independently using their choice of elements, and the supervisor also exchanged with the student and rated all the student's elements on the student's constructs. This is important, because one objective in collaborative learning is to reduce the impact of the power differential between "teacher" and "learner" and create a single "learning community."

6. Linking to MultiMedia on the Web

A system operating through WWW should be capable of using the hypermedia facilities of the web. WebGrid allows annotation to be added to any element ("Edit Notes" button in Fig. 7). This annotation is in HTML so that it can include diagrams, pictures and links to other web documents. Figure 14 shows a grid being developed on presidential policies where the elements "Eisenhower" and "Kennedy" match, and the student has decided to add another construct to break the match. The HTML annotation includes pictures of each president and hypertext links to major issues during their terms of office. Figure 15 shows the annotations that generate the images and links shown in Figure 14.

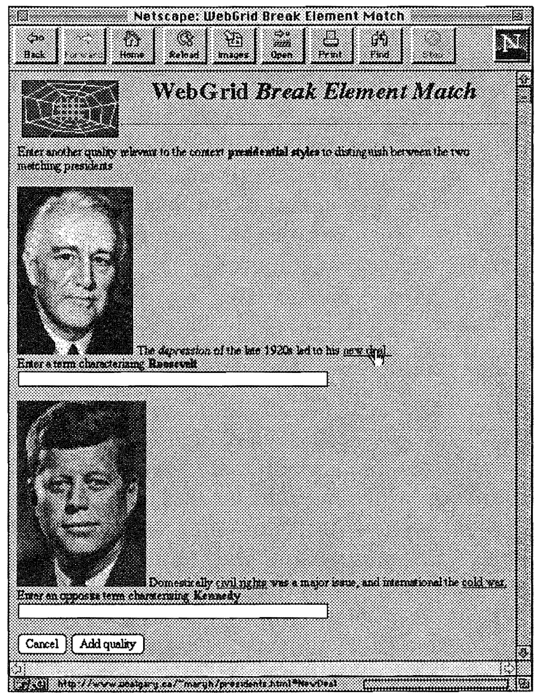

Figure 14. WebGrid links to multimedia annotation.

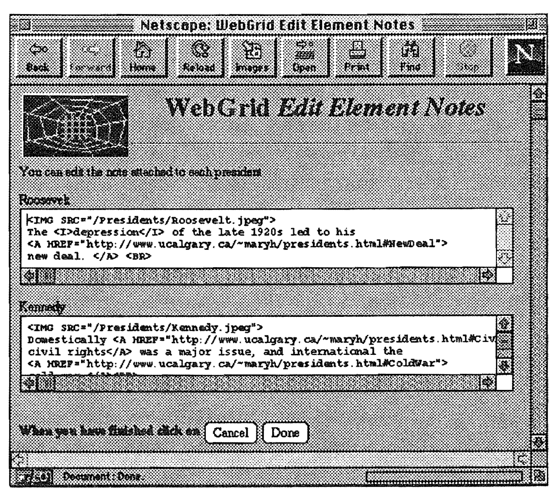

Figure 15. WebGrid annotation entries.

7. Experience with WebGrid in Courses

Constructivist tools that allow students to investigate the relativity and pluralism of perspectives in human society are particularly important in disciplines that still teach primarily from a positivist stance [17]. The 'received wisdom' stance of much science teaching is inappropriate to the employment environments of computer scientists. They need to become *reflective practitioners* in Schön's [18] terminology, because they will need to continually adapt throughout their careers to social change in which their discipline plays a major role. Computer science teaching generally follows the tradition of "privileged knowledge" in which it is the business of the instructor to impart knowledge. Students are fed "knowledge" in measured portions, expected to digest it, and give evidence through assignments that they have done so.

A more operational view of knowledge takes a constructivist approach to learning in which understanding is based on active participation in the subject matter and reflection on conversations with others on the topics of a course. This is the Schön's "reflection-in-action" in which learning is a joint enterprise, leading to a less authoritarian model.

An example of a course in which WebGrid plays a significant role is CPSC 547, advanced information systems for Computer Science majors. Students work collaboratively in groups of 2 to 4, and make their materials available to the class of some 50 students through the web and through demonstrations. The students in this course are preparing for a new industrial infrastructure which has seen the end of the large-scale information systems divisions that used to dominate computer science employment opportunities. Hundreds of information systems professionals have already had to come to terms with a new industrial environment that emphasizes small, adaptable, entrepreneurial organizations. Our graduating students need skills that go beyond mere technical proficiency to cope with the new challenges and opportunities.

A classroom environment suitable for reflective learning is best based on the recommendations and beliefs of Carl Rogers [19] for generating a positive atmosphere in which students exhibit mature everyday behavior, are less defensive, more adaptive, and more able to meet situations creatively. This involves treating each student as an individual, being available to discuss problems individually and help with students' decision-making, creating a supportive and empathic class atmosphere in which each student is given positive encouragement to discuss issues of concern, and making the instructor's own thoughts and views genuinely available for discussion.

After a few lectures, the students in CPSC 547 take over the course and run it through their own group research, presentations and demonstrations addressing major issues in advanced information systems. The students work extremely hard, are incredibly motivated and enthusiastic, achieve a very high standard of work, and think deeply not only about the technology but also about the social and ethical implications of its applications. WebGrid allows them to explore different perspectives on the world in a structured fashion leading to results that can be presented to others and discussed within the groups and with the class as a whole.

8. Conclusions and Future Directions

When we commenced the development of WebGrid, knowing the limitations of HTML forms, we had no great expectations that the resultant tool would be attractive to use. We have spent many years carefully developing user interfaces with good human factors targeted on repertory grid elicitation, and knew the need for special-purpose graphical "widgets" that could not be emulated in HTML. We are enthusiastic users of World-Wide Web for publication, and use it extensively in courses where each instructor and student has a home page and together develop a "learning web." We were interested to see what could be achieved with more interactive, collaborative tools, but felt that the technology might not yet be adequate for what we wanted to achieve.

We were more than pleasantly surprised by the human factors and attractiveness of WebGrid. The free-form HTML documents with embedded widgets in many ways gave us more flexibility than we had experienced in the design of the original RepGrid interface, and interaction with WebGrid has proved natural to our student communities. From a programming perspective, HTML forms provide a cross-platform graphic user interface (GUI) that is simple to prototype, easy to customize, and whose simple primitives help to support the basic human factors guidelines of *uniformity* and *consistency* [20].

One objective in the original WebGrid development was to preserve the stateless nature of the HTTP protocol. No data is stored at the server between transactions. In particular, this makes it possible for us to offer WebGrid as an open service on the web without being concerned about managing the storage of other people's data. However, we are also concerned to support collaborative communities as we have done with RepGridNet [10, 11], where members can make their grids available to the community. This raises many problems of authorization, protection, and so on. It is not easy to design a system for the web that has open, easy access, yet avoids data loss or unwanted interference through careless or deliberate actions. WebGrid already supports one user saving their grid locally and linking it to their home page to make it available to others. However, this is an awkward way of supporting an identifiable community, and we are developing a general GroupWeb facility that supports distributed databases of community information, including repertory grid data.

In conclusion, we hope that the example of WebGrid will encourage others to develop interactive collaborative learning systems on World-Wide Web. It is a rich environment for collaboration whose potential we have barely begun to comprehend, let alone tap.

Acknowledgments

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WebGrid may be accessed at:
http://tiger.cpsc.ucalgary.ca/WebGrid/

A Postmodern, Constructivist and Cooperative Pedagogy For Teaching Educational Psychology, Assisted by Computer Mediated Communications

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Abstract

Student reactions/evaluations were associated with diverse pedagogical structures including Cooperative Learning (**CL**), Computer Mediated Communication (**CMC**) and Writing Across the Curriculum (**WAC**) which were all used to deliver graduate instruction in Educational Psychology courses. The approach was predicated on the assumption that students authentically construct knowledge from their experiences within a social context of peer influence. Reflective writing in the context of a public forum in which students were required to react to each other's writing engaged students in a process of critical thinking. They were required to maintain an electronic journal which consisted of weekly narratives (postings to a "netnews group") which consisted of reflections on classroom activities and related readings. Classroom activities included the use of a writing activity described as a Dyadic Essay Confrontation (**DEC**). Students were required to react to a randomly determined partner's reflections within one week after the initial reflection. A final narrative reflection was required to be submitted to the newsgroup detailing a summary analysis of the constructed knowledge they had determined was brought about through this process. Their reflections and reactions and summary/conclusions comprised a major product for inclusion in an electronic portfolio which was submitted at the end of the class. The techniques, as well as how this complex structure was implemented, and, how students responded to the electronic medium are discussed. Using a rationale derived from the WAC community that stresses integration of the writing process across the curriculum, the conclusions focus on using CMC as an integral part of classroom instruction. A Postmodern and Constructivist theoretical orientation is used to explain the positive student responses to this complex of authentic instruction.

Keywords — Cooperative Learning, Writing, Computer Mediated Communication.

1. Introduction

Lewinian-oriented psychologists subscribe to the theory that human behavior is a result of the interaction of persons with their environments. This has lead to many speculations on **"ACTION THEORY."** An action theory examines the actions needed to achieve a desired consequence in a given situation. Johnson & Johnson (1987) have stated that "when you generate an action theory from your own experiences and then continually modify it to improve its effectiveness, you are learning experientially (p. 16-17). Experiential learning has three effects: 1) cognitive structures are altered, 2) attitudes are modified and 3) behavioral skills are expanded, and this is a cyclical process. The Johnsons (1987) have presented 12 principles of experiential learning , of which the last four focus on the influence of environments on individuals, especially within the context of a social group. Membership in a group which is supportive and accepting will free a person to experiment with new behaviors, attitudes, and action theories. One such group might be a cooperative classroom structured for learning. The Johnsons (1979) have differentiated three types of classroom **goal structures** including 1) cooperative, 2) individually competitive, and 3) individualistic. These goal structures are primarily based on the notion of the presence or absence of positive interdependence among classroom members. One form of cooperative learning has been labeled **"Collaborative Learning"** and has been used extensively in the teaching of writing at the post-secondary level of education (Bruffee, 1993). Cooperative goal structures are in operation when two or more individuals are in a situation where the task-related efforts of individuals help others to be rewarded (positive interdependence). Group members behave in a **positively** interdependent fashion and are rewarded on the basis of the quality or quantity of the group product according to a fixed set of standards. Sherman's (1990; Millis, Sherman & Cottell, 1993) Dyadic Essay Confrontations (DEC) is considered to be an example of a cooperative technique.

Giroux (1990, p. 35) has stated that "...critical educators need to provide a sense of how the most critical elements of modernism, postmodernism, ... might be taken up by teachers and educators so as to create a postmodern pedagogical practice." The present author has tried to adapt and apply relativistic and constructionist viewpoints by introducing conceptual conflict (disequilibrium) into teaching. An additional concern has been to challenge and foster higher level cognitive processes by encouraging critical integration, synthesis, evaluation and analysis of knowledge. The pedagogical practices described below uses the medium of writing and cooperative discourse associated with computer mediated communication. In the spirit of "authentic instruction," (Newmann & Wehlage, 1993), outcomes of this pedagogical strategy are believed to be: 1) increased higher-order thinking; 2) greater depth of knowledge; 3) more connectedness to the world beyond the classroom; 4) substantive conversation; and 5) greater social support for student achievement.

2. Method

2.1. Sample

The students who have experienced the strategies described below were graduate education majors pursuing Master's and Specialist's degrees in Elementary and Secondary Teacher Education, Family and Consumer Sciences, Educational Leadership, and Educational and School Psychology. The two 3 credit hour classes examined in this report were taught one evening per week throughout a 15 week semester. Classes varied in size from 20 to 21 students.

2.2. Procedures

The **DEC** technique was used in ten short essay writing experiences which were assigned throughout the semester. For further details and earlier reports on DEC see Sherman (1988 & 1990) as well as Millis, Sherman & Cottell (1993). Bolling (1994) has discussed maintaining group journals as a means by which students may effectively "collaborate." Individual journals are difficult to share among one's classroom peers. Group journals are at least shared among a small group. My approach has been one of extending the notion of a group journal, to a series of journal entries which are constantly available to all class members (**Narrative CMC Journals).** In this sense the entire class of students become resources for each other. This has been accomplished by utilizing CMC in the form of a "news group". Within the context of Miami University's computing environment we maintain an entity called "NETNEWS." This is a "USENET-like" environment where I established a newsgroup for each of my classes. Students are required to make weekly postings, called "reflections," after each class meeting. Within one week after they have posted a "reflection" they are required to "react" to other classmates' reflections. Throughout a 15 week semester, each student posts 12 reflections and 12 reactions. Reflections are made to several aspects of each weekly meeting including simulations, video tapes, whole class discussions, lectures, and the DEC's. They have assigned readings from textbook chapters as well as primary author articles. The DEC activity usually involves two other students, each of which is writing an answer to some one ease's prepared questions, or reacting to someone else's answer to their own question. The three DEC members are randomly determined each week. This determines the people whom they must "react" to in the following weeks netposting. Throughout a typical semester, then, each student reacts to many different people in the class. And, their reflections and reactions are available to all other class members.

3. Results and Analysis.

3.1. Dependent measures and analysis

Newmann & Wahlege (1993) have developed a survey instrument consisting of five items designed to tap students' perceptions about authentic instruction. These five items request students to rate on a five-point (1 to 5) Likert scale their perceived class experiences. Perceptions with regard to 1) higher-order thinking [THK], 2) depth of knowledge [KNW], 3) Connectedness to the world beyond the classroom [CON], 4) conversation [COV], and 5) social support for student achievement [SSA] are the primary focus of this survey. It was anonymously filled out on the last day of the class. Descriptive and comparative statistics are used to describe these results presently based upon 41 graduate students from two classes: 21 respondents from a Fall, 1994 advanced Educational Psychology class, and 20 students from a Spring, 1995 class dealing with group dynamics in the classroom.

3.2. Survey Results

1. DOES THIS CLASS ENCOURAGE HIGHER ORDER THINKING?: (low-order thinking 1 to 5 high-order thinking)

Class	Mean	SD	F	p<
FALL 94	4.38	0.50	5.52	.02
SPRING 95	3.90	.79		

2. HOW DO YOU FEEL ABOUT THE DEPTH OF KNOWLEDGE OBTAINED IN THIS CLASS?: (knowledge is shallow 1 to 5 knowledge is deep)

Class	Mean	SD	F	p<
FALL 94	3.24	1.09	3.23	.08
SPRING 95	3.80	.89		

3. IN THIS CLASS WHAT IS THE LEVEL OF CONNECTEDNESS TO THE WORLD BEYOND THE CLASSROOM: (no connection 1 to 5 highly connected)

Class	Mean	SD	F	p<
FALL 94	4.09	0.88	0.00	.0
SPRING 95	4.10	.85		

4. IS THERE SUBSTANTIVE CONVERSATION IN THIS CLASS?: (no conversation 1 to 5 high-level substantive conversation)

Class	Mean	SD	F	p<
FALL 94	4.33	0.97	3.36	.07
SPRING 95	3.75	1.07		

5. IS THERE SOCIAL SUPPORT FOR STUDENT ACHIEVEMENT IN THIS CLASS?: (negative social support 1 to 5 positive social support)

Class	Mean	SD	F	p<
FALL 94	4.04	0.92	0.82	.37
SPRING 95	4.30	.86		

4. Conclusion

DEC is based on postmodern thought including the concepts associated with transactional theories of rhetoric, cognitive elaboration and arousal, paradox, divergence and plural realities. DEC, is a continuation of the author's earlier and continuing concerns for promoting learning through small group discussions (Sherman, 1986; Millis, Sherman & Cottell, 1993). The addition of the narrative reflection/reaction component, as facilitated by the NETNEWS group, made possible a continuing dialogue outside of class time. The classes receiving this type of strategy generally felt that it was highly beneficial to their learning of both the content of the class and about each other's perceptions of that content. While the strategies described in this essay obviously take up more instructor time in reading, responding and evaluating, it is believed that the gains in student writing abilities and critical thinking (rhetoric), and the motivating stimulation of the class discussions are worth the efforts. The special issue of Teaching of Psychology (Nodine, 1990) which is devoted entirely to "Psychologists Teach Writing," has several articles expressing similar sentiments. However, it should be noted that virtually all of the articles contained in that issue focus on individual student writing projects, rather than cooperative or collaborative classroom pedagogical strategies. The only article weakly linking a peer-tutor cooperative strategy was Levine's (1990). While some of the authors acknowledge the dialogue which takes place between instructor and student, none of the articles recognize the peer interactive models available in cooperative learning. Five years later in the February, 1995 special issue of Teaching of Psychology (Volume 22, Number 1) devoted to "Psychologists Teach Critical Thinking," nearly 60% of the articles mention some form of cooperative learning, however, only one of the articles utilizes computer based technologies (Wolfe, 1995). Thus, increasing use of writing appears to be happening, but inclusion of computer-based technologies, especially in the form of CMC, does not seem to be as prevalent. Lastly, while the rich variety of psychology theories associated with the field of educational psychology is eminently suited to this technique, it is believed that many other disciplines which likewise abound in diverse theory could benefit from this approach.

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URL=http://MIAVX1.MUOHIO.EDU/~LWSHERMAN/CSCL95.HTML/ .

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Collaborative Distance Education on the World Wide Web: What Would That Look Like?

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Abstract

This paper suggests a possible application of the World Wide Web for distance teacher training in the area of mathematics education. INSTRUCT (Implementing the NCTM School Teaching Recommendations Using Collaborative Telecommunications) is designed to introduce secondary mathematics instructors to the *Professional standards for teaching mathematics* (NCTM, 1991) while fostering a sense of community among teachers who are physically removed from each other. Emphasis is placed on blending synchronous and asynchronous technologies to facilitate sustained interaction and real-time application of concepts. Options contained within INSTRUCT include a hypermedia version of the Professional Standards for Classroom Teaching, links for connecting to on-line educational resources, the ability to attend synchronous meetings with other INSTRUCT users, opportunities to join in asynchronous discussions, and general access to the Internet. Three key research questions concerning this type of technology are discussed: The amount of face-to-face training required for teachers to become comfortable using INSTRUCT, the extent to which collaboration features of INSTRUCT must be formalized to ensure involvement by participants, and whether use of INSTRUCT can foster among teachers a sense of self-worth and community resulting in lasting change in practice.

Keywords — collaborative telecommunications, distance education, secondary mathematics, teacher training, World Wide Web.

1. Introduction

The Internet has existed in various forms since the late-1960s. However, it was only with the development of the World Wide Web (WWW) and the subsequent introduction of graphical browsers such as Mosaic and Netscape that the Internet moved from being a text-only communications tool to being a powerful multimedia platform whose potential applications are still being investigated (Schatz & Hardin, 1994). Among these applications, the WWW sites dedicated to instruction are generating new interest in the uses of computers in distance education. In many cases these sites merely represent classroom materials, such as syllabi or class notes, which are available as an outside resource to students enrolled in a course. However, there are at least a few WWW sites offering individuals the opportunity to complete a course remotely, without the need for attendance in class. As these sorts of applications are contemplated, we believe it is essential to include a consideration of the collaborative learning tools that will provide necessary interaction and foster a sense of community for those individuals isolated by geography or other constraints.

2. Background

The focus of this paper is on the use of WWW for distance teacher training, specifically in the area of mathematics education. Teachers in North Carolina, as in many other states, are required to participate in inservice staff development as a part of a licensure renewal cycle which repeats every five years. This training normally takes the form of workshops conducted at a single site over the course of several days or even several weeks, typically during the summer months. Drawbacks to this type of staff development include the time and money required for travel to the training site; the artificiality of training done in isolation of the classroom, wherein teachers must wait until the school year begins again to apply their learning; the logistical problems of attempting to support teacher change once teachers have returned to their schools; and the difficulty inherent in trying to keep teacher training current in a discipline such as mathematics education where knowledge and practice are rapidly evolving.

Various distance education solutions proposed for use in teacher training have addressed the above shortcomings. Mayes (1993) developed a series of master's level math courses that were transmitted via a two-way satellite link to teachers at statewide regional sites in West Virginia. Knapczyk (1991) has reported on a distance system for training teachers to manage at-risk students which provides an audiographic link via telephone lines between groups of participants. Both of these projects were able to overcome many of the difficulties of face-to-face instruction, including travel and associated costs, while fostering a sense of collaboration among teachers. Yet, the present authors do not feel that the full potential of telecommunications for teacher training has even begun to be tapped. As Knapczyk (1991) states:

> *Improving the skills of personnel already teaching in elementary and secondary public schools requires that universities generate new approaches to their K-12 staff-development activities.* (p. 68)

In the spirit of this recommendation, we have begun exploring the use of WWW for teacher training. Using this technology, training and support would be available to teachers at their schools during the school year, and the on-line training and resource materials could be updated on a continual basis in order to maintain teacher awareness of current trends. Further, we believe that sufficient interactivity can be built into the system so that teachers will feel that they are a part of a community of educators despite potentially being the only workshop participant at their school.

3. The Design

The distance teacher training system we are developing is a Mosaic page called INSTRUCT, which stands for Implementing the NCTM School Teaching Recommendations Using Collaborative Telecommunications. The initial target population for INSTRUCT is secondary mathematics teachers, but it is our desire that the training resources available through INSTRUCT would eventually be appropriate for K-12 teachers involved in mathematics instruction. Brush, et al. (1994) has identified some important aspects of distance performance support systems intended for use with practicing teachers:

> *...a support system for distance instruction would need to aid in the delivery of the content of the training, to provide a mechanism for interaction between instructors and students, to offer options for feedback about assignments and projects, and to give the program staff alternatives for evaluating the training and maintaining quality control over activities.* (p. 39)

Guskey (1986) elaborates on the need for promoting interaction among participants involved in training, noting that most teachers require the opportunity to share ideas and concerns with others before making changes in their instructional practices.

INSTRUCT's design therefore integrates aspects of groupware, or software intended to support group interaction, to expand its use beyond being simply a storehouse of instructional material. Johnson-Lenz and Johnson-Lenz (1991) have suggested that groupware attempt to strike a balance between supplying mechanisms for encouraging interaction and providing open spaces within which participants determine the types of interaction that take place. As Mandviwalla and Olfman (1994) suggest, users should also have the capability to meet synchronously or asynchronously, as appropriate, and the tools for carrying out these interactions should be contained in a single system.

Following is a listing of the options available through INSTRUCT with a description of their function:

A. A hypermedia version of the NCTM Professional Standards for Classroom Teaching found in the *Professional standards for teaching mathematics* (NCTM, 1991)

This choice will link the user to a Mosaic page with the following menu items: Worthwhile mathematical tasks, Teacher's role in discourse, Student's role in discourse, Tools for enhancing discourse, Learning environments, Analysis of teaching and learning. Each of these sub-menu items will lead to other Mosaic pages which employ text, images, audio and video to provide the user with a multimedia introduction to the NCTM standards for classroom teaching. Each sub-menu page will contain its own "Check for Understanding" form for the user to fill out and submit electronically to the training coordinators for assessment of the user's mastery of a particular standard.

The NCTM *Professional Standards* includes vignettes intended to act as exemplars of the standards in practice. Similarly, INSTRUCT will provide the user with multimedia vignettes to enhance and clarify presentation of the training material. Teachers will be given the opportunity to be involved in the project as contributors of pictures, audiotape and videotape of classroom activities for use in multimedia vignettes. The use of authentic classroom materials, such as written records of student problem solutions (Figure 1) or checklists of observed problem-solving behaviors, is intended to make INSTRUCT both practical and useful for the continuing education and support of mathematics teachers.

Out of a concern for minimizing download time for these large multimedia files, trainees will be given a CD-ROM containing these files which can be accessed through the use of small Toolbook routines contained within INSTRUCT. This will solve the problem of users waiting potentially long periods of time to view multimedia vignettes. Additionally, by tying questions in the Check for Understanding forms to material contained in the CD-ROM, training coordinators can better control teacher access to INSTRUCT for the purposes of receiving licensure renewal credit.

B. On-line educational resources

Choosing this menu item will link the user to a Mosaic page of educational resources currently existing on the World Wide Web, each of which will in turn link users to the desired WWW site. Available sites will include K-12 Schools On-line, NASA Langley Research Center's K-12 Program, U.S. Department of Education WWW Server, and the NCSA Education Program.

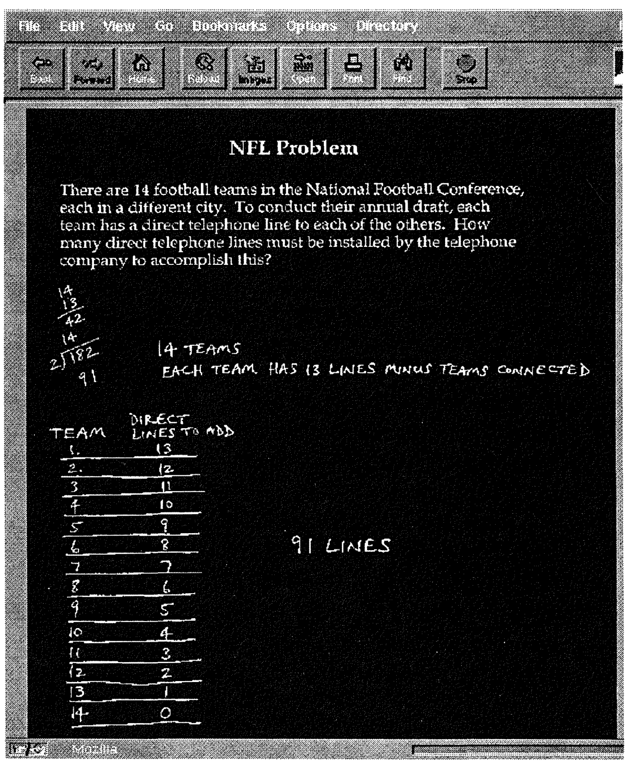

Figure 1. Example of authentic classroom materials available through INSTRUCT.

C. Attend a meeting

This menu choice will provide a telnet connection to a synchronous multi-user dialogue area (e.g., wb or Collage). Meeting participants will have a shared whiteboard and chat box within which they can display and annotate text, images and graphics (Figure 2). In order to promote teacher active participation in and application of INSTRUCT training, trainees will be given assignments to carry out in their own math classes. An intentional by-product of these assignments will be to encourage the need for sustained interaction and collaboration among participants and coordinators (Honey & McMillan, 1994). The meeting option would be particularly useful for INSTRUCT training coordinators to provide additional training materials and commentary to users, for trainees who wish to meet with an INSTRUCT training coordinator regarding their progress, or for users who wish to get together on-line to brainstorm about classroom ideas and plans.

D. Join in a discussion

This option will connect users to a dedicated list server where they can asynchronously communicate with other INSTRUCT users at their own convenience. Scardamalia and Bereiter (1993) urge that for asynchronous communication:

> *The flow of information must allow for progressive work on a problem, with ideas remaining active over extended periods of time and revisited in new and unexpected ways.* (p. 38)

The format being suggested here would benefit teachers by allowing them the opportunity to be involved in more long-term discussions about issues raised in the NCTM Standards, by facilitating the sharing of news and other items of interest between colleagues, and by affording users continual access to previous communications via discussion histories.

E. Send a message

This choice will provide general Internet access for making a meeting appointment, for asking a question of a training coordinator or colleague, or for conducting a database search (e.g., using Gopher).

A long-term goal for INSTRUCT is that teachers would continue to use the program after completion of the Standards training. The menu options for on-line resources, meetings and discussions provide users with

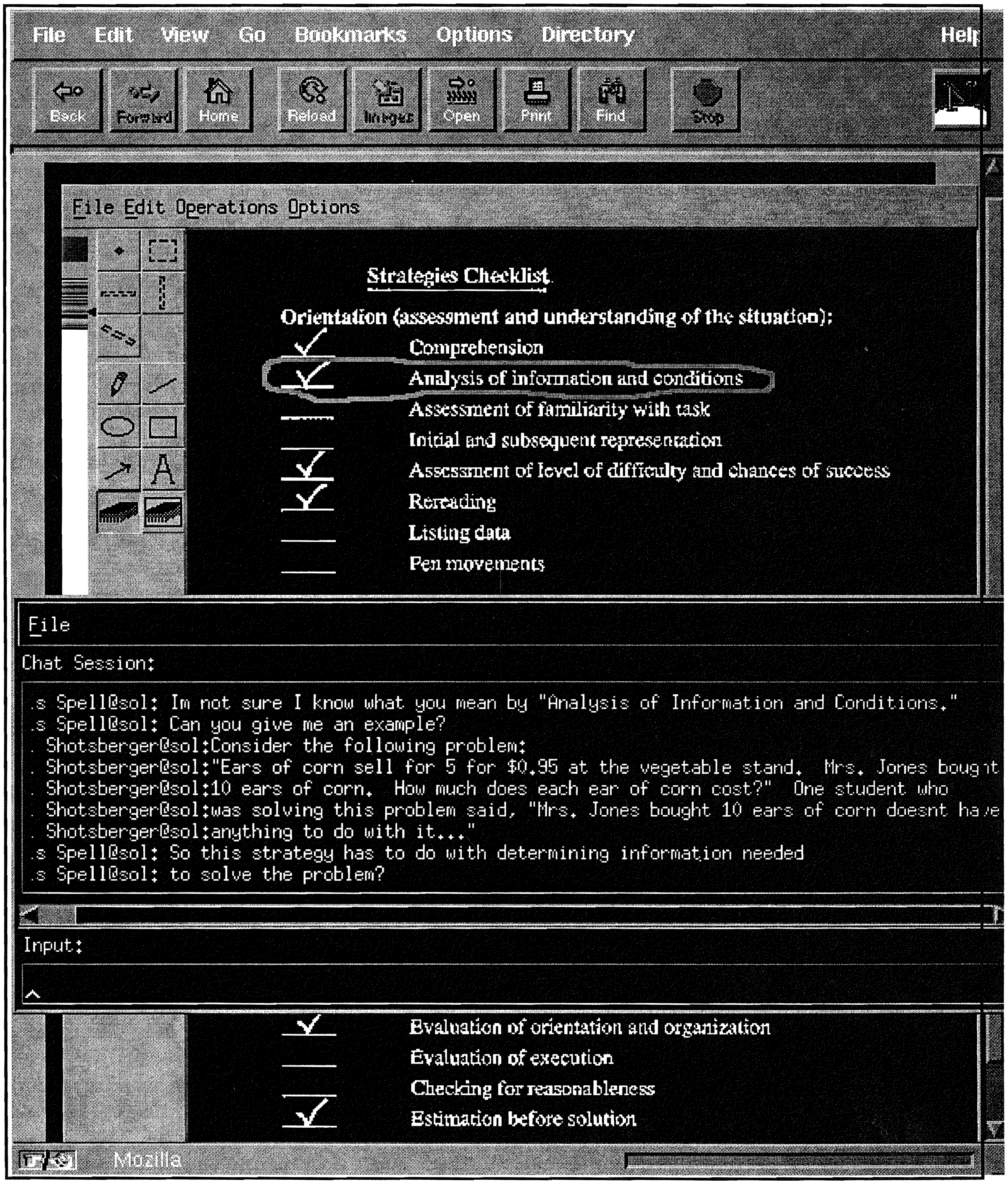

Figure 2. Sample INSTRUCT synchronous meeting.

resources which can enrich classroom teaching on an ongoing basis while providing support for teacher change. Further, an essential feature of Mosaic pages is that they are extensible and easily modified. The developers envision other training modules being added to INSTRUCT, so that it can grow and change to meet evolving teacher licensure/training needs.

4. Research Issues

There exist many research issues surrounding the use of collaborative tools in distance education. First, it is likely that some of the teachers who would be using INSTRUCT would have no prior experience even with simple telecommunications tools such as electronic mail. Therefore, an essential question to address is the amount of face-to-face training needed to allow trainees to become comfortable with the use of telecommunications in general, and shared workspaces in particular. Likewise, once users are engaged in distance training, INSTRUCT must be able to satisfy a user's need for continued support during the school year. Important considerations are the appropriate mixture of synchronous and asynchronous contact required by users to support their continued use of INSTRUCT, and how comfortable users are expressing their feelings and opinions about making changes in their classroom instruction as a result of training.

A second area of concern is the extent to which collaboration features of INSTRUCT must be formalized to ensure involvement by the participants. Research on computer tutors and microworlds indicates that if the use of options for investigation and experimentation depends on user initiative, it is likely the tools will not be employed (e.g., Lewis, Bishay & McArthur, 1993). Similarly, there is a concern that allowing INSTRUCT users too much freedom with regard to scheduling synchronous meetings or being involved in asynchronous discussions will result in under-utilization of the collaborative aspects of the program. The question then becomes how much formalism need be imposed on the INSTRUCT environment by the training coordinators, and to what extent this formalism needs to be tailored to individual users.

One of the direct benefits of face-to-face training is the sense of community and self-worth teachers derive from taking part in professional training with colleagues from other schools. Therefore, a third research issue revolves around the question of whether use of INSTRUCT can foster among participants these critical components of effective teacher training. We believe that inclusion in a virtual community of professionals through participation in this unique brand of distance education will result in a reduced sense of isolation and increased self-esteem. Further, participants will be encouraged to apply their training over a longer period of time, resulting in more enduring change in their instructional practice.

These issues provide a notion of the key questions that need to be considered. Collaborative distance education offers new teaching opportunities and a vast, rich arena for research. INSTRUCT will possess the capability for recording user protocols and discussion histories, and this information combined with teacher interviews and questionnaires should begin to address these and other issues.

5. Summary

Mosaic and WWW hold tremendous potential for easily accessible, up-to-date training and support of teachers. INSTRUCT employs this new distance education technology for introducing secondary teachers to the NCTM standards for classroom teaching, while providing a framework for collaboration with colleagues and resources to promote lasting change in their instructional practices.

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Toward Supporting Learners Participating in Scientifically-Informed Community Discourse

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Abstract

In traditional high school classrooms, learning science means reading textbooks, listening to lectures, and conducting a few disconnected, out-of-context laboratory experiments. If one of the goals of science education is to produce citizens who can respond and act capably around science-based issues in their communities, we must support a new perspective on the way science is taught, and to some degree, the things that are taught in science classes. To support this new perspective, we provide the rationale and framework for a collaborative computer-based modeling, discourse, and decision making system currently under development, called RiverMUD.[1] RiverMUD is a multi-user domain in which students conduct scientific inquiries within a virtual community.

Keywords — theories of collaboration and learning; design and interface issues; microworlds, MUDs, and multi-user simulation.

1. Introduction

Several recent reform movements in American education have called for changes in the goals of science learning, leading toward new conceptions of scientific literacy. For example, The American Association for the Advancement of Science's Project 2061 [1], calls for changes in the way we envision scientific literacy. The authors of "Science For All Americans" define scientific literacy in the following manner:

"The scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and ways of thinking for individual and social purposes." ([2], p. ix)

Traditional classrooms based entirely on a didactic teaching approach typically have difficulty accomplishing the goal of producing scientifically-informed, knowledge-using citizens called for by the reform documents. However, a newer perspective based on constructivist and sociocultural theories presents an alternative to the didactic approach. These theoretical frameworks provide the principles and evidence for establishing *collaborative, contextualized, knowledge-building and knowledge-using environments for learning*. They lead us toward the definition of pedagogies, like project-based science, and to the design of computational tools like RiverMUD that support the creation of communities around the production and use of scientific knowledge.

The constructivist paradigm has led us to understand how learning can be facilitated through certain types of engaging, constructive activities. For example, learners should be able to formulate hypotheses and questions, predict, work with information to decompose a topic into sub-topics, gather data from a variety of sources, organize diverse and contradictory information, and so on. Defining, building, and using models of scientific phenomena is one specific undertaking in which learners can begin to develop these cognitive skills as well as build and use scientific knowledge. Furthermore, the sociocultural perspective of learning has led us to a better understanding of activity and practice, and how learning is accomplished through situated, cultural activity. This model of learning emphasizes meaning-making through active participation in socially, culturally, historically, and politically situated contexts. A crucial element of active participation

[1] A more detailed discussion of the design rationale and theoretical framework for RiverMUD is available in [5].

is dialog in shared experiences, through which situated collaborative activities, such as modeling, discourse and decision making, are necessary to support the negotiation and creation of meaning and understanding.

2. Realizing Theory In Tasks: Modeling, Discourse, and Decision Making

We have identified three tasks, modeling, discourse and decision making, that, when synergistically combined in computational tools like RiverMUD, enable the development of learning environments suggested by the learning theories and help attain the goals of scientific literacy.[2] RiverMUD provides a shared experience in virtual communities established around scientific modeling activities to contextualize discourse and decision making. The key to the success of combining these three tasks lies in the ability to create an authentic, shared context for activity while providing tools to support the modeling, discourse, and decision making activities. In RiverMUD, the shared context in which users collaborate and interact is a shared model of some real-world phenomena (e.g. a river ecosystem). To facilitate the use of this shared context, RiverMUD provides tools for manipulating the model and for communicating about the scientific phenomena being modeled.

The shared RiverMUD context is a collaborative virtual reality – an appropriate medium from the constructivist perspective and sociocultural perspective since it allows students to immerse themselves in a culture, participate in constructive activities, and then to step back and reflect upon the activities. In the virtual world, students actively participate to construct meaning in socially, culturally, historically, and politically situated contexts. These simulated environments can encourage a civic understanding to the scientific activities and provide a historical-political sense to scientifically-informed group discussion and decision making. These virtual experiences, when linked to real experiences, enable the attainment of the broad understandings of science and its uses required by the goal of scientific literacy.

3. Learner-Centered Design Applied to Tasks

To address the issue of how to develop collaborative tools, we must develop collaborative software based upon the needs of learners. Learners are also users so standard user needs form the foundation of a learner's needs. Above and beyond the basic user needs we must also consider the learner's need to grow, the diversity of individual learners and the wavering motivation of learners [3]. The primary means by which software addresses the needs of learners is through scaffolding. Scaffolding is an educational term which refers to providing support to learners while they engage in activities that are normally out of their reach.

To build scaffolds which support learner's needs we apply Learner-Centered Design. LCD is a constructivist and socioculturally-based task, tool and interface scaffolding design strategy to support authentic, project-based, learning environments [4]. When scaffolding the task, we must pay specific attention to the growth of the learner. To address the diversity of learners we must scaffold tools to provide support for different learning styles and levels of expertise. And finally, when designing interfaces we must focus on the students motivation [4]. These principles form the foundation upon which we design software scaffolds.

Table 1 illustrates the translation of an educational goal of argumentation to an implementable software strategy through the application of learning theory. The scenario in Section 4 will help to illustrate these scaffolding strategies.

4. A Scenario: RiverMUD In Use

The following scenario illustrates one way in which RiverMUD may be used in a high school science curriculum. The tasks (and their corresponding sub-tasks) that were derived from the science literacy goals are indicated in brackets throughout the scenario.[3]

During a two week period in a month-long curricular unit on water ecosystems, students in several classrooms participate in a project using RiverMUD. During the unit, students can collect data and conduct research on water ecosystems in their area; the use of RiverMUD provides students with an environment where they can build understanding and apply their scientific knowledge to real-world situations.

Before the students begin using RiverMUD, the teacher facilitates a discussion of modeling and its basic applications in scientific inquiry. This helps provide a basic understanding of the definition of modeling and establish a foundation upon which the students build their work. Further, students contemplate the relationship between the model instantiated in the virtual world of RiverMUD and the real world, leading to a good understanding of the parameters of the simulation [MODEL: DEFINITION].

When students first begin using RiverMUD, they are invited to explore a world of interconnected places populated by objects. (For example, two sections of a stream, where there is a factory in the upstream section and a housing complex downstream.) Students can move from place to place within the confines of this virtual world, examining the objects they encounter. They can look at individual characteristics of those ob-

[2] A full discussion of these tasks and their associated sub-tasks is available in [5].

[3] A more comprehensive scenario and integration of tasks and sub-tasks is available in [5].

Table 1. Translation of Educational Goals to Implementable software Strategies

Learning Goal	[ARGUMENTATION]: To make an argument the student must justify their points and counterpoints based upon scientific principles, evidence, definitions, and experience.		
Learners Needs	Growth	Diversity	Motivation
Learning Environment Element	Tasks	Tools	Interface
Scaffolding Strategy and Theoretical Rationale Examples	Reduce task complexity by structuring the task into discrete steps (that relate to the student's mental representations). Provide authentic activity which contains culturally-embedded supports for accomplishing tasks.	Support different learning styles, cultures, and levels of expertise by providing tools that afford the use of multiple symbol systems and representations.	Present a somewhat familiar and personalizable interface to provide a culturally-meaningful environment. Provide visualization of the task to represent the content or process in ways that enable understanding, thus maintaining a sense in learners that they can do the task.
Software-Realizable Scaffold Examples	Provide students with a Propose/Debate/Vote Mechanism that provides direction and organizes the discourse.	Provide students with a variety of media such as text, drawings, pictures, and models to support argumentation.	Provide digitized image of student shown next to their arguments. Display arguments in different ways based on their position towards the proposal.

jects, as well as the web of relationships connecting those characteristics. (For example, the amount of pollution put into the river by the factory upstream affects the water quality downstream, which affects the algae, which affects the fish, and ultimately affects the homeowner who swims in the river and eats the fish.)

Students are then invited to participate in modifying and extending the world.[4] At first, students make minor changes to the objects in the model to bring them more into line with observations made in their own real-world data collection [MODEL: USE]. Eventually, student groups are formed and each is given responsibility for an area of the model. Students can read an online "newspaper" about the historical role their group is to play in the virtual world. For example, if a certain group of students had gathered water quality data from an industrial park, they could be assigned the role of industrial cooperative within the model. Another group, having gathered data in a residential subdivision, discovers they have been assigned the part of a land developing firm with financially concerned stockholders. In the virtual newspaper, each group further reads about problems it must confront: the cooperative faces a shortage of electrical power; the land developers must deal with a solid waste disposal problem. To address these issues, each group must propose to the virtual community, concrete changes in the virtual world [MODEL: CREATE], along with a reasoned defense of the appropriateness of the change [DISCOURSE: ARTICULATION]. The computational medium, with its strict accounting of how the elements

[4] In other projects, students may be encouraged to build their own worlds using the RiverMUD modeling tools.

of the virtual world are related, is then able to determine which other participants are likely to be strongly affected by the proposed change [DECISION MAKING: IMPLICATIONS]. Using this information, the medium engages a synchronous debate mechanism. Those affected by the proposal are invited to make arguments for or against it, using a variety of media [DISCOURSE: ARGUMENTATION]. The debate ends when all participants have entered their votes [DECISION MAKING: POSITION]. Then, if a majority has approved the proposal, the model is altered to incorporate the change. As a result of this change, a newspaper article is automatically generated reporting the nature of the change and an accounting of who and what has been affected [DECISION MAKING: SCOPE]. The article also summarizes via excerpts from the debate leading up to the change and may even present data from the model before and after the change was implemented. This process continues throughout the unit as students interact in the model and read and contribute to their newspaper about issues and crises they must address.

At certain points during the project, the teacher may facilitate a discussion of the relationship between modeling, decision making, and discourse in the context of student activities in the virtual world. Other activities may include discussions facilitated by guest speakers who have experience with issues tackled by the students in their simulations, and field trips to real sites that actualize situations encountered by the students in RiverMUD. It's important to continue to draw parallels between the virtual and real worlds so students can reflect on the roles modeling, decision making, and discourse play in our society. We expect that by grappling with the threefold challenge of understanding and using models, communicating arguments based on those models, and participating in community decision making, students will come away with ideas for how scientific inquiries are conducted and how science and technology can be used to make important personal and social decisions.

5. Concluding Remarks

The tasks supported by RiverMUD were derived from conjoining constructivist and sociocultural theory with the science literacy goals defined in many of the current educational reform documents. We then applied learner-centered design principles to define scaffolds in RiverMUD to assist students in the completion of the tasks.

The constructivist and sociocultural frameworks together provide a wealth of principles to assist with the design of new learning environments that support effective learning. RiverMUD, a collaborative computer-based modeling, discourse, and decision making system is an instantiation of these theories and can support the production of citizens who can act responsibly around science-based issues in their communities.

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Internet Repositories for Collaborative Learning: Supporting both Students and Teachers

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Abstract

Most efforts to create computer-supported collaborative learning environments have been focused on students. However, without providing appropriate integration of collaborative activities into curricula, these efforts will have little widespread impact on educational practices. To improve education through technology, learning environments for students must be integrated with curriculum development tools for teachers to create an integrated collaboration-oriented classroom. This paper describes how software tools for Internet repositories can aid fundamental collaboration activities—locating, using, adapting, and sharing—at both the teacher level (with the Teacher's Curriculum Assistant) and the student level (with the Remote Exploratorium). It illustrates how tools for educators and tools for students can be orchestrated into integrated classroom support.

Keywords — Computers, networks and other technological developments relevant to CSCL; educational distance groupware; design and interface issues.

1. Collaborative Activities Require Support

The goal of encouraging groups of learners to engage collaboratively in problem-solving activities has much merit. Social interaction fosters deep learning in which students develop intellectual structures that allow them to create their own knowledge [27]. It promotes social skills that help people participate in the social construction of their shared reality [3]. It increases student engagement and brings out the relevance of learning [16]. It allows the educational process to be more student-centered, less disciplinary, and more exciting [14, 15].

The use of technology to foster collaborative learning is often seen as a key to reforming science education—on the principle that the best way to learn science is to engage in the practice of science [10]. The practices of modern science involve the use of technologic tools for:

- observing and measuring interesting phenomena in the world,
- generating representations and visualizations of the data, and
- creating simulations to understand observed processes and to test hypotheses.

Importantly, the practice of modern science is highly collaborative. Scientists work together to incrementally design experiments and simulations, to convergently develop hypotheses and theories, and to test and evaluate their work [17, 22]. Many projects have successfully combined these elements to foster innovative forms of collaborative science education among students [8, 12, 24, 26].

However, research projects have often been unable to transfer their successful results to other sites or schools because they did not replicate the initial teacher learning that occurred implicitly in the teacher-researcher and teacher-teacher collaborations [21]. For educational change to succeed, teachers too must be supported in changing from an isolated teaching model to one of collaborative learning with other educators [4]. We believe that for collaborative learning to succeed in the classroom, collaborative learning activities for students must be integrated with collaborative curriculum development resources for teachers. To implement collaborative learning in the classroom, students can be offered activities that provide a focus for group exploration; teachers need curriculum to provide contexts for these activities. Student activities can, for instance, build upon simulations of scientific or mathematical phenomena. Classroom contexts for these activities can include background information, ideas of approaches for students to try, ways for teachers to provide guidance, complementary activities for other groups in the same classroom or for outside of class, supplementary readings, examples of what other groups produced through similar activities, and possible variations to adapt the activities to specific local circumstances or to personal preferences.

Toward this end, we have developed two innovative software systems: one primarily for students and one primarily for teachers. They illustrate how tools for teachers and students can be orchestrated into integrated classroom support. The Remote Exploratorium (RE) [1] supports students and teachers in collaboratively using and developing interactive learning simulations of scientific phenomena. Our experience testing RE in schools is that efforts to use these simulations are largely futile without appropriate integration into curricula and without providing teacher support. The Teacher's Curriculum Assistant (TCA) [25] addresses this shortcoming by helping teachers and learners locate, use, adapt, and share lesson plans that illustrate how systems such as RE or KidSim [23] can be used in classroom settings.

For innovative forms of collaborative education to achieve widespread use, dissemination mechanisms are required that make tools and materials available to parties other than those participating in particular research projects. We have chosen to use the Internet and the World Wide Web (WWW) as distribution mechanisms. However, our work and other experiences [9] have shown that simply making materials available is not sufficient to foster a collaboration medium where teachers and students share innovative ideas. Computer support for students and teachers should also assist with several activities associated with collaboration—especially locating, using, adapting, and sharing.

Consider how the Internet functions now, as an unstructured repository of ideas for activities and for curriculum. People have posted their pet ideas on diverse Internet sites and in various formats. It is difficult for students or teachers to find sites that have offerings and to search through the offerings to retrieve those that are relevant. There is no support for adapting the activity ideas to actual classroom situations or for sharing experiences using these ideas with other students and teachers. In particular, the following activities are problematic:

- **Locating.** Students and teachers have no systematic guide to where to look on the Internet. They may hear of WWW locations from various sources and then surf around looking at individual offerings until they become lost or tired. Once repositories of ideas for activities are found, there is no uniform way to search through the offerings to find those that meet current needs. Some sites may provide primitive query mechanisms, but these vary from site to site.

- **Using.** Most Internet postings give only brief descriptions of ideas for activities. They do not provide the resources needed to carry out the activities, nor do they provide curriculum to create a productive context for the activities.

- **Adapting.** For learning to be effective, students must make the activities their own; they must be able to modify the activities and put their stamp on them. Teachers must also be able to adapt the activities and curriculum to the personal learning styles of the students and to the characteristics of the classroom and the priorities of the local school district. Simple postings do not facilitate this.

- **Sharing.** For the Internet repository to work as a collaborative medium, students and teachers who benefit from the repository must be encouraged to participate in its growth and evolution. They need tools that make it natural and easy to contribute their new versions of activities and curriculum and to annotate repository offerings they have used with their experiences. Students and teachers cannot post responses at most sites where items are found.

The remainder of this paper begins by presenting a use scenario that illustrates collaboration-oriented classroom support. Next, we present the two systems we have developed, RE and TCA. Finally, we discuss barriers we have encountered developing and using these systems. It is our hope that by identifying such barriers we can instigate further discussion and promote directions of change that will help make the Internet and the WWW more effective media for educational collaboration.

2. Collaboration-Oriented Classroom Support

The following diagram illustrates a scenario of classroom use of RE and TCA. The scenario shows how this software supports locating, using, adapting, and sharing simulations and related curriculum. On the left and the right of the diagram are two classrooms (see Figure 1). They may be widely separated in time and space.

The teacher on the left has downloaded a TCA curriculum on ecology. This teacher has posed the question, "Why are ecosystems fragile?" The students have been told to find simulations of ecologies. They have turned to RE and located a simulation of a frog pond. After downloading it, they run it; populate it with frogs, flies, and alligators; and observe what happens. Then they use it, varying the parameters that describe the quantities and behaviors of the creatures. If they are advanced users, they create their own new creatures with interesting behaviors and study the consequences of their introduction. Finally they upload their new simulation for others to use. The teacher extends the ecology curriculum to include activities targeted at introducing new species into existing ecosystems and observing population dynamics.

The teacher on the right uses TCA to search for curriculum on ecology and locates the version that the first teacher modified. Students in this classroom select a simulation of sharks in the ocean from RE. Their teacher adapts the curriculum to the new simulation and poses the question added as a result of the first class' work, "What happens if too many of one species are added to an ecosystem?"

3. Remote Exploratorium: Tools for Students

We have developed a design environment called Agentsheets [20] that can be used to create construction kits, simulation environments, visual programming languages, and games. Design environments are tools that allow groups of learners to construct artifacts meaningful to them. The process of designing serves as a vehicle to create opportunities for learning [2], and the use and modification of simulations of scientific phenomena forms a basis for collaborative activities in the classroom [12]. Many of the existing Agentsheets titles allow groups of students to set up, run, and modify simulations of scientific and mathematical phenomena [19].

Recently, we have combined the Agentsheets design environment with the Mosaic networking medium to create the Agentsheets Remote Exploratorium [1], providing learners access to interactive exhibits (Figure 2). Students can actively interact with exhibits including Electric World (an exhibit to experiment with electricity), and Waves (an exhibit to experience the Doppler effect and supersonic booms). The easy inclusion of additional information, such as instructions, learning motivation, and even related references for further exploration, is supported through the use of Mosaic and creates an interactive exhibit which contextualizes educational use. RE supports fundamental collaboration activities by allowing students to progress through several layers of usage:

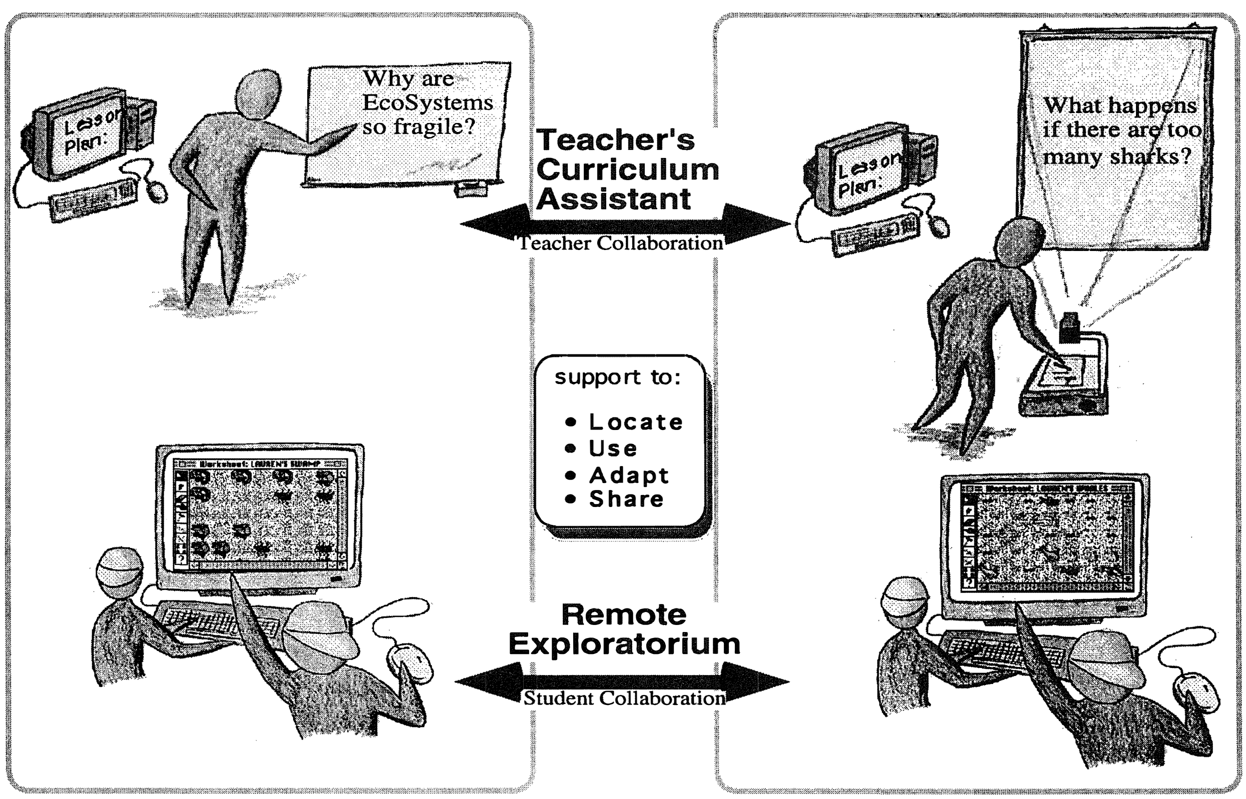

Figure 1. TCA and RE support collaboration of teachers and of students to develop repositories of simulations and of associated curriculum.

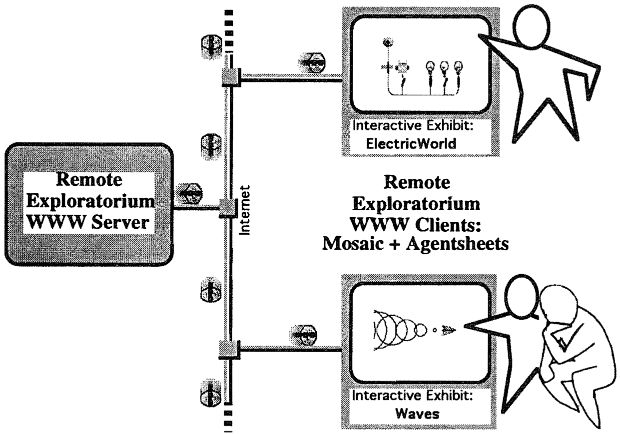

Figure 2. Remote Exploratorium: Servers and Clients.

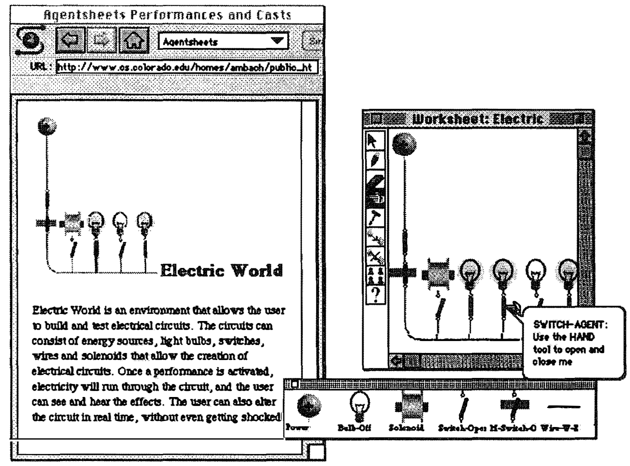

Figure 3. The Electric World Exhibit.

3.1. Locating: Navigating through the Exploratorium

Exhibits are linked to other sources of related information located on the WWW. The learner makes use only of the Mosaic part of the virtual exploratorium to find interesting related information consisting of text, pictures, and videos. The Exploratorium may be visited on WWW at URL:

> http://www.cs.colorado.edu/~l3d/remote-exploratorium/AgentsheetsRemoteExp.html.

Classrooms must have the Agentsheets player to run simulations.

3.2. Using: Downloading and Running Exhibits

If learners are interested in a deeper understanding of an exhibit, they can download it and run it. For instance, the Electric World exhibit is about electricity. In the Electric World Mosaic page (Figure 3, left), the learner can click the download option to access the interactive exhibit. In response, Mosaic sends a compound document to Agentsheets. The Agentsheets design environment loads sounds, installs agent depictions, compiles agent programs, and stores agent documentation. The learner sees two new windows on the screen: a worksheet in which the simulation takes place (Figure 3, right top) and a gallery of agents (Figure 3, right bottom) containing electrical components. Simple documentation describing the behavior of agents and means to interact with agents can be accessed through Macintosh Balloon Help. The balloons, like the code, depiction, and sound of agents have been transferred from the RE server via the Mosaic WWW client to the Agentsheets design environment. In the Electric World learners can operate switches and observe reactions. For instance, operating the left most switch in the lower row of switches will put the circuit into a feedback mode in which an electric coil and the electromagnetic switch located left of the coil will interact with each other.

3.3. Adapting: Constructing New Simulations and Extending Behavior of Exhibits

Exhibits are not static artifacts to be observed. Learners have all the components to create new simulations or to change existing ones. In Figure 4 (left side), the learner has added a column of switches. By doing this, learners can directly and tangibly apply knowledge gained from the exhibit.

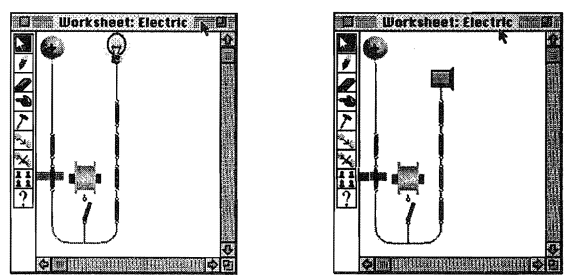

Figure 4. The changed Electric World is shown on the left. Adding a buzzer to the circuit is shown on the right.

Students can also change their role from end-users to designers by using Agentsheets functionality to modify the behavior of an exhibit. For example, learners can add their own agents to exhibits. In the Electric World a learner introduces a buzzer by first defining its depiction, , using the Agentsheets depiction editor, and then defines the behavior of the buzzer either using a textual programming language called AgenTalk or using graphical rewrite rules. The new buzzer agent is ready to be used in the Electric World (Figure 4, right side). It serves as a replacement for the bulb. When the buzzer receives current, it plays a sound. This extensibility allows an exhibit to be customized to support what is most relevant to the learner, and to reflect shifts and changes in the learner's acquired knowledge.

3.4. Sharing: Adding New Exhibits

Efforts are underway to extend RE to support participants in posting changes to existing exhibits and even adding entirely new exhibits. Currently, contributors must contact the Exploratorium curator via email.

4. Teacher's Curriculum Assistant: Tools for Teachers

The Teacher's Curriculum Assistant [25] is a design environment to support the curriculum development needs of classroom teachers. It accesses a special TCA curriculum repository on the Internet that points to educational resources such as RE and other learning resources available over the Internet. The design of TCA supports fundamental collaboration activities in the following ways:

4.1. Locating: Searching for Distributed Curriculum Sources

The first problem with using the Internet as a source of curriculum ideas is the distributed nature of the Internet. Resources may be located at thousands of sites around the world and there is no central listing of all these locations. TCA addresses this problem by requiring all postings to adopt a standard form of indexing and to register their indexes at a central site for TCA users. Thus, when someone wants to offer a new Agentsheets simulation, they fill out a form specifying what grades, subjects, etc. the title is appropriate for. An index record is created for the title, including this information and the location of the title on the Internet. Periodically, teachers using TCA update the database on their computers with new index records. All curriculum structure as well as indexes for the multimedia resources are kept on the teacher's desktop computer; only the resources themselves (text, pictures, video clips, spreadsheet templates, HyperCard stacks, software applications) need to be downloaded.

TCA provides a combination of query and browsing tools for searching the indexes in its database. This combination is designed to respond to problems in information retrieval in unobtrusive ways. Queries are notoriously difficult to formulate and brittle to execute. People cannot generally articulate specifications for the information they want. They need to see what is available and then gradually focus in on a set of interesting results [18]. Simply browsing through large informa-

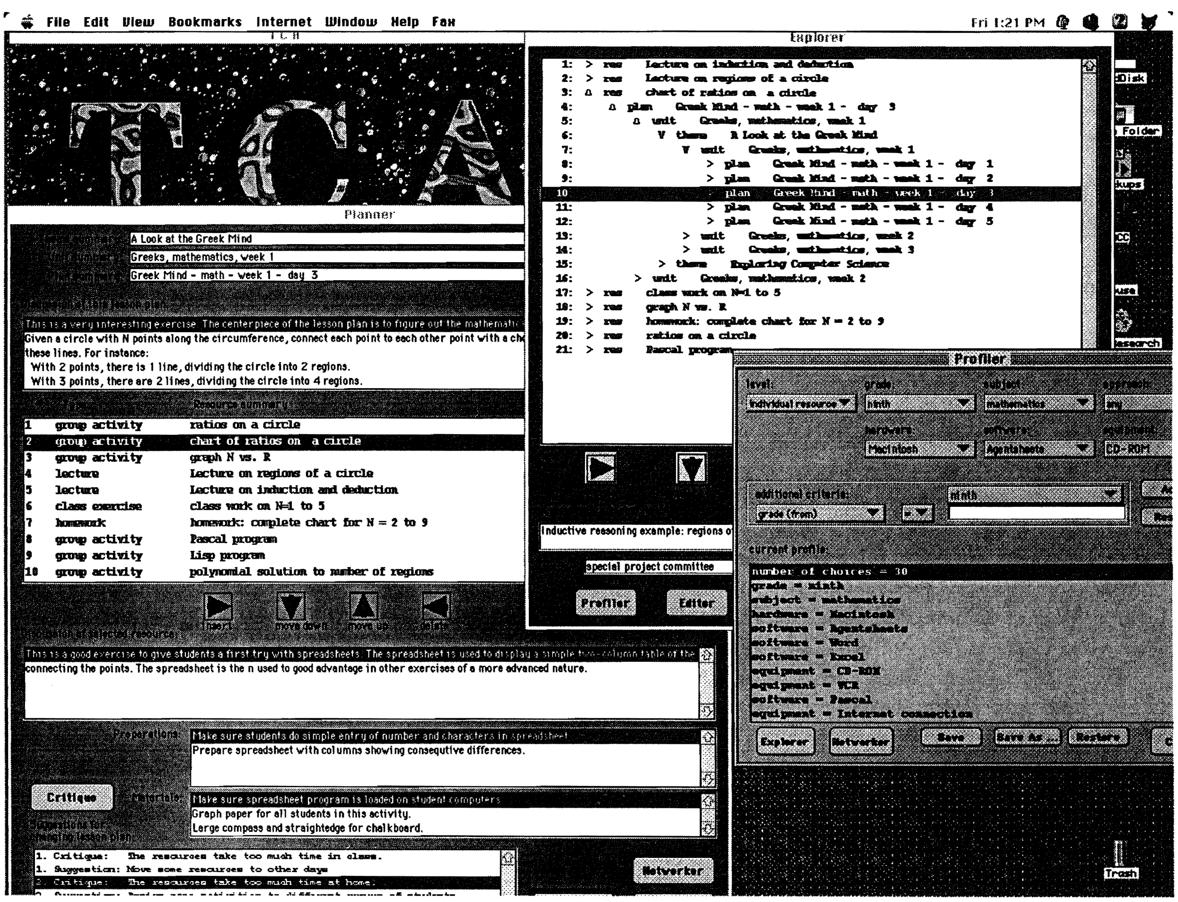

Figure 5. The TCA Profiler, Explorer, and Planner windows.

tion spaces, however, has its own pitfalls. People get distracted and lost; they lack an overview and focus [7].

TCA provides a classroom Profiler (Figure 5, far right blue window) for teachers to specify the characteristics of their classrooms. The Profiler gathers information for queries by collecting facts about a teacher's classroom. For instance, what is the grade level and subject; what hardware and software are available; what pedagogical approaches are preferred? Then, when a teacher decides to explore curriculum on the Internet, TCA automatically generates a query for just those curricular resources.

Once teachers have located a promising set of curriculum using the Profiler, the Explorer (Figure 5, middle red window) can be used to browse through this smaller, more manageable amount of information. The Explorer lets a teacher traverse through four levels of curriculum: semester themes, weekly units, daily lesson plans, and individual resources. In Figure 5, for example, a teacher displayed a number of resources for ninth grade mathematics in the Explorer window. She then expanded the third resource to find a lesson plan built around this resource by pressing the up arrow. Continuing, she found a weekly unit that included five coordinated lesson plans. In this way, the teacher found sample curriculum to use with the selected resources and to adapt for a week of activities that would promote her pedagogical goals.

4.2. Using: Downloading Educational Resources

Teachers can efficiently perform searches on their own computers to find which of all the curricular resources on the Internet are most suited to their needs. Only when it comes time to actually use the resources do they need to download the ones they want. TCA downloads them automatically using the location information in the indexes.

4.3. Adapting: Tailoring Educational Resources and Curriculum to Local Needs

TCA provides several support mechanisms to help a teacher adapt curriculum and resources to actual classroom needs:

- Computational critics (rule-based mechanisms for evaluating designs [6]) in the TCA system compare the user's profile with the indexes for a given curricular item and suggest changes to eliminate incompatibilities

- The TCA system uses case-based reasoning adaptation rules [11] to make changes automatically, based on incompatibilities between the profile and indexes; the teacher can accept or reject these changes.

- A teacher can use commercial applications from within TCA (word processors, spreadsheets, Agentsheets) to modify resources created in those applications.

- The lesson Planner in TCA can be used to modify curriculum themes, units, and plans, while the Editor window can be used to change the indexing of resources.

The lesson Planner (Figure 5, left green window) allows teachers to build lesson plans by adding and rearranging resources, such as textual readings, group activities, collaborative research topics, and class presentations. Teacher preparation instructions and materials requirements from all the resources in the lesson plan are displayed together to help the teacher get ready for a class.

4.4. Sharing: Posting New Curriculum to the TCA Server

The networker component of TCA allows teachers to download and post to Internet sites, and thereby to share in the collaborative process of curriculum development. It lets teachers download any indexes that have been posted since they last updated. It also lets them upload their contributions, for instance to post modified versions of curriculum or new resources. This component is used to set up details for Internet usage, such as phone numbers and sites for maintaining TCA indexes.

5. Discussion

We encountered several issues while creating RE and TCA that we believe to be barriers to the use of Internet and WWW technology as collaboration media:

Reliability: Imagine if a student were using a textbook and that textbook periodically disappeared without warning. This situation, although an Internet reality, is unacceptable in widespread educational use of distributed educational resources such as RE.

Efficiency: Exhibits in RE require not one, but several files containing various types of information (e.g., sound, pictures, code). Participants have a low tolerance for files that require many minutes to be downloaded successfully, however file compression and aggregation is not supported within the network media. To address this problem in TCA, the information teachers need for planning is maintained on their computer. Options are provided that allow teachers to schedule the downloading of large educational resources overnight or in other less critical times.

The Sharing Bottleneck: Barriers to true two-way collaboration over the Internet and WWW fall into two categories: technical and institutional. On the technical side, only very limited mechanisms for feedback are currently supported within WWW client software. For the most part, interaction is limited to selecting from provided options or entering small amounts of text into forms. On the institutional side, there are many policy decisions to be made and processes to be worked out concerning verification and authentication of posted materials. For instance, who should verify (if anyone) that posted exhibits actually compile and run? On a more ominous note, what policies and mechanisms are required to ensure that simulation agents with malicious behaviors, such as deleting or scrambling data, are detected before widespread dissemination occurs? Many institutional issues are also raised by the attempt to establish a curriculum repository. Sanctioning and endorsements of TCA require policy decisions. For instance, should posted curriculum be reviewed against some criteria concerning suitability for the claimed audience or other educational content concerns? Who will make these decisions and what are the criteria? One solution is to have several curriculum servers, some mediated by providers of curriculum, others open.

Standards are Required: We have tried to design computer support tools to help students and teachers take advantage of the Internet as a repository of activities and curriculum. In doing this, we have found that the repository itself must take on structure. The Internet imposes little structure; that is why the world's largest library is the messiest that has ever existed [13]. The WWW imposes useful structure with its hypertext mark-up language (HTML), and newer alternatives like Hyper-G are imposing more structure to permit higher functionality [5]. RE introduces a file type for transmitting Agentsheets titles. TCA defines indexing formats for curriculum. The construction of our tools for students and teachers takes advantage of these structures. In suggesting structures, we have tried to balance the needs of standardization with the goals of open-ended collaboration.

Institutional Collaboration is Required: Before a system such as TCA can achieve widespread use, the indexing scheme it proposes must be accepted as a standard by providers of curriculum and educational resources. Institutions such as federally funded curriculum development efforts, textbook publishers, and software developers must collaborate to seed TCA with a critical mass of information, and a community of teachers must begin to use it.

6. Summary

We started with Agentsheets, an environment for creating simulations that can be used for collaborative activities of students. This needed to be supplemented with a means for distributing new titles and allowing students to find titles that met their needs. RE was designed to use the WWW as a medium for students and educators to share simulations and other interactive learning environments. Classroom experience with Agentsheets showed the need for providing curriculum contexts for the simulations. TCA is an attempt to establish a medium for teachers to collaborate around a growing body of curriculum. This effort in turn points out the need for institutional collaboration to form a community of users that accepts the standards proposed by TCA. In conclusion, we have found that classroom support requires support for teachers as well as for students. Such support should cover the activities of locating, using, adapting, and sharing. Only when these activities are supported, can networking media be transformed into collaboration media.

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LEAP: A Constructivist Laserdisc Program for English/Language Arts Teacher Education

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Abstract

Literacy Education: Application and Practice (*LEAP*) is video-case based laserdisc program designed to give preservice teachers an opportunity to observe and analyze real-world situations in a collaborative learning environment. *LEAP*'s structural design is based on the principles of cognitive flexibility hypertext, a constructivist approach to using laserdisc technology for instruction. Exploration of 23 mini-cases (naturalistic portrayals of three middle school teachers) is guided by themes: teacher role, student role and environment.

This paper discusses the results of the field testing of *LEAP* and describes how interactive video-case methodology did provide a shared environment for dialogue and self-reflection in an English/language arts teacher education program.

Keywords — Video-case methodology, teacher education, literacy.

1. Introduction

The subject matter that a middle and high school English/language arts teacher teaches as well as how it is taught are issues that have historically generated controversy and change in American curriculum (Applebee, 1974, Berlin, 1987). Current debates concern issues such as whose literature constitutes the "canon," what skills should be taught, and what theoretical and ideological assumptions underlie pedagogy (Elbow, 1990). One particular topic has captured the interest of educators: the reading/writing workshop approach (see Atwell, 1987, and Rief, 1992 for a detailed description of the approach). Tenets of the workshop approach call for a constructivist learning environment. That is, the reading/writing workshop classroom is a student-centered milieu in which reading and writing are taught holistically in meaningful contexts, and unique, individual responses to literature are valued and encouraged. Because it is based on constructivism, it differs from the more traditional English/language arts methodology that hinges on the mastery of isolated reading and writing skills and the "correct" interpretation of literature.

A number of publications and textbooks are available for helping pre-service English/language arts teachers and teacher educators to explore and comprehend the various perspectives on the application and practice of the workshop's constructivist approach. The education of these future teachers could be enhanced, however, through the use of video-case instructional programs such as those used for the preparation of professionals in other complex domains (see Spiro & Jehng, 1990). Such video-case methodology creates a *macro-context*, a rich environment for such knowledge construction and self-awareness because it provides the preservice teacher with an opportunity to explore authentic classroom interaction from many perspectives.

When video-cases are delivered on laserdisc, the video representations being explored can be accessed readily, randomly and repeatedly (Spiro & Jehng, 1990). Teachers-in-training can visit and observe the same classroom without having to physically travel to the school location, as is commonly the practice for students attending colleges and schools of education. Most importantly, laserdisc technology allows small and large groups of preservice teachers to access, play, pause, and replay video-cases as they construct meaning that is based on their observations and influenced by the ensuing group dialogue.

2. Creating a Prototype of *LEAP*

An 18-month qualitative study was conducted to investigate the process of designing, developing and evaluating a video-case laserdisc-based instructional support program that a) is specific to the professional development of English/language arts teachers, and b) focuses on the application and practice of the reading/writing workshop approach. A prototype of an interactive laserdisc program named *Literacy Education: Application and Practice* (*LEAP*) was created and field-tested. This research critically analyzed results of the field test as well as examined the process of design and development that culminated in the prototype's three major components:

- A laserdisc containing 23 naturalistic (not rehearsed or scripted) video-cases featuring three experienced, middle school teachers who use the workshop approach and their students.
- Software that allows learners to randomly explore the mini-cases and to analyze and critique precepts of the workshop approach from various perspectives.
- A collection of seminal literature concerning the underlying theory and current practice related to the reading/writing workshop.

2.1. Research Questions

Three research questions guided the study. Two of these concerned the procedures of designing and developing the *LEAP* prototype. One question concerned the field testing of *LEAP*: What changes in perspective related to the teacher's role, student's role, and learning environment of an English/language arts classroom are revealed in the observations of and interviews with teachers-in-training as they interact with *LEAP*?

This paper will focus on the field test, and specifically on the collaboration that occurred within small groups as they interacted with *LEAP*. It will first outline *LEAP*'s structural design, then present the results of the field test, and finally, discuss the implications of the data analysis.

2.2. Design

LEAP's structural design is based on the principles of cognitive flexibility hypertext, a constructivist approach to using laserdisc technology for instruction. The most prevalent feature is that learners' exploration of 23 mini-cases is guided by themes: teacher role, student role and environment. Subthemes within each of these provides information about how teachers and students interact and about the elements of a workshop environment. A writing with video feature was added to the ingredients of cognitive flexibility hypertext. This feature provided a means for video-supported oral presentations.

Three goals were determined for *LEAP*:

- To provide thematic "paths" for exploration by which the whole class, small groups, or individuals can explore the video-cases of experienced language arts teachers.
- To facilitate the formulation of concepts related to literacy education among preservice teachers as they draw from models described in text and from observation and examination of teachers on video.
- To provide a forum, a shared experience, for discourse which could generate contextualized impressions and help to identify assumptions of the reading/writing workshop in specific and the teaching of literacy in general.

2.3. Development

Each of the middle school teachers were recommended by their school district's administrators and video-taped for four days. A two-hour tape of 43 mini-cases was culled from the 22 hours of raw footage. The tape was shown to four experts on the reading/writing workshop approach who were asked to rate each mini-case on a Likert-type scale. Based on these ratings, 23 mini-cases were selected and edited so that they would fit on two 30-minute sides of a CAV laserdisc.

Five main menu options guide the user through the *HyperCard 2.2* stack that controls the laserdisc player. The options are the following: *Teacher Stories, Themes, Creations, Re-Views, and Sources.*

- *Teacher Stories* allows the user to choose a teacher and view all of the video corresponding to her.
- *Themes* guides the learner through the mini-cases based on three very broad themes--teacher role, student role, and environment--or through 28 subthemes listed under the broad themes such as the following:

  Teacher Role - Teacher as Guide
  Teacher Role - Teacher as Learner
  Student Role - Student as Reader for Pleasure
  Student Role - Student as Negotiator
  Environment - Comfort Objects
  Environment - Technology

- *Creations* allows the student to write a response to what was viewed. These comments are stored and are accessible to other students to read. A unique highlight of this feature is that they are also able to write with video. That is, they can insert video clips into their writing.
- *Re-Views* provides the professor or the programmer the option of selecting a video clip and asking the students a question regarding that clip. This screen can be projected so that it serves as a visual aid to help guide class discussion. It can also be viewed by students individually.
- *Sources* gives the user an annotated bibliography of books on the reading/writing workshop.

3. Field Testing *LEAP*

A field test was conducted at a private university; 29 preservice teachers and their professor were observed as they used *LEAP* for eight weeks. Data was collected by video-taping and transcribing sessions and presentations, collecting questionnaires, and conducting interviews.

The students were asked to select a book of their choice from the *LEAP* collection and then form groups of 3-4 people to explore the mini-cases and prepare a presentation using the *Creations* component of *LEAP*. Eight groups met in a technology lab for 2 hours on one week and 2 hours on the following week.

3.1. Observations

Observations of the lab sessions and of the video-tapes of the sessions indicated that all of the groups relied on the general guidelines provided by their instructor to determine their course of action. Guidelines included open-ended questions designed to prompt the students as they prepared their presentations.

Based on an analysis of the transcripts of dialogue that occurred during the lab sessions, six general categories of discourse were recognized:

- All groups discussed their interpretations of the books read. These interpretations were not always directly related to the mini-cases, but they were most often triggered by them. Some of this talk was critical interpretation, but much of it was descriptive.

- Anecdotes/comments related to personal experience were often discussed by all groups. Usually comments about personal experiences were negative when memories were compared to what was perceived in the mini-cases (student autonomy, teacher support).

- Some groups engaged in debates on what is traditional and what is non-traditional in the mini-case scenarios and which approach is better for the student and for the teacher.

- Conversations often centered on some of the concepts labeled as subthemes, particularly, "teacher as learner," "reader/author for pleasure," "author's chair," "unrestricted space," and "comfort objects." For the majority of the students, the constructivist terminology of the reading/writing workshop approach was unfamiliar.

- Some of the dialogue concerned how to use the software and hardware, and often this discussion included the lab assistant. Most of the assistance requested from the groups regarded the software functions. Although every screen had a help button available, the group members preferred to ask their questions directly to the lab assistant. By the second session in the lab, most of the groups had very few questions.

- All groups engaged in discussion concerning what questions to choose to answer from those offered in the guidelines, what each member of the group would contribute, and how the presentation would be evaluated.

3.2. Questionnaires

Responses to a questionnaire collected before and after *LEAP* were compared. The questionnaire asked the respondents to identify their goals as teachers of literacy and their expectations of their students. It also asked them to describe a reading/writing workshop. An analysis of the content indicated that there was more variety in the types of responses after the *LEAP* experience. Also, terms associated with the reading writing workshop approach were found in the respondents' descriptions of goals. Verbs used to describe the goals in the post-*LEAP* responses were more student-centered than those found in the pre-*LEAP* responses. Several respondents said they would use the reading/writing workshop approach. All confidently defined the workshop approach.

The subjects were also given a questionnaire to determine what they considered the strengths and weaknesses of *LEAP*. Their responses indicated that they enjoyed being able to experience the reality of classroom. Another frequently stated response was that the experience with technology was beneficial and pleasant. They attributed the positive experience to their finding that *LEAP* was user-friendly. Negative comments regarded a lack of time and the need to flip the laserdisc. Various suggestions for improving minor mechanical capabilities were given, but highly ranked among the responses was the message that no improvements were necessary. In general, the instructor's comments mirrored the students: *LEAP* is a user-friendly program that provides active learning opportunities, but more time is needed. She also suggested that giving the students a broader background on theory would enhance their experience.

The preservice teachers' language suggested that they had internalized some of the precepts of the constructivist instructional methods of the workshop and they were able to recognize the existence of differing perspectives on how literacy is taught. In much of the dialogue in the lab sessions as well as in the ideas expressed in the presentations, there is evidence that the students had conceptualized a polar view of approaches: the traditional approach and the reading/writing workshop approach. In many cases, the students situated themselves within a constructivist circle, on the reading/writing workshop side. In some of the lab sessions, however, students outlined a clear division of teacher-centered and student-centered approaches but also attempted to align themselves with both in varying degrees. For example, they agreed with student autonomy but they stressed the need for structured grammar drill, standardized testing, and teacher accountability. Or they praised the workshop advocates' propositions but admitted that they probably would not tolerate students laying on the floor or on bean bags to read (images portrayed in the mini-cases). In general, the richer vocabulary of the post-*LEAP* discourse was interpreted to mean that the students certainly had a more lucid awareness of their own perspectives on their role as teachers, on the role of their students and on the environment of their own future classrooms.

4. Conclusion

LEAP was designed to provide a *macro-context*, a rich environment for knowledge construction and self-awareness. The results of this qualitative study confirmed that the preservice teachers who field-tested *LEAP* did engage in rich dialogue triggered by the video-cases, the books, and their recollections of classroom experiences.

Had they adopted a *new* perspective, however? The majority of the students stated that they were not familiar with the approach before *LEAP*, and the education courses at this field site did not include instruction on the workshop approach. The authors of the sample essays were overwhelmingly in favor of the workshop approach after *LEAP*, and half stated their intent to use the approach in their classrooms. A comparison of the goals the preservice teachers expressed before their experience with *LEAP* and after it supports the conclusion that many of them had adopted a new approach, at least momentarily.

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The Enabling Impact of Information Technology: The Case of the Ohio University MBA

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Abstract

This paper describes how information technology is used to enable an action-learning based MBA program. All graduate students in three separate sites have access to the OUMBA Information Network. Students and faculty collaborate electronically using Lotus Notes. Learning materials are provided electronically. Students present reports electronically. It is demonstrated how effectiveness and efficiency of learning and collaboration are enhanced via this application of technology.

Keywords — information technology, collaboration, cognitive constructivism, teamwork.

1. Introduction

In 1986, Ohio University initiated a radically redesigned MBA program. The redesign was prompted by the extensive criticism of MBA programs that was popular at that time and our own assessment of the quality of the educational experience we were providing students. The redesign was based on published criticisms of MBA programs, our discussions with leaders of potential employing organizations, and our own study of the future nature of business and the implied required characteristics of workers.

The initial innovation in the MBA curriculum was the institution of a year-long holistic "course" called integrated business analysis (IBA) and a companion year-long behavioral skill development program. The IBA used a problem-based learning pedagogy to simultaneously developed target knowledge, skills, and personal characteristics.

After seven years experience with the redesigned program, multiple assessments of its impact, and continued study of the evolving needs of the business community, we determined that it was time for another radical redesign. The present program was developed during the 1993-94 academic year and implemented August of 1994. [For a more in-depth discussion of the development and implementation of the OUMBA see Milter and Stinson, 1995 and Stinson and Milter, 1995.]

2. The Ohio University MBA

The program, as it is now structured, is an intense 13-month learning experience, starting in August of the first year and concluding in September of the second year. The program uses an action-learning format with a theoretical base in cognitive constructivism. This design places learners into the type of projects and work situations that they will face as a leaders of information-age organizations in the 21st century. Students learn basic business concepts, but learn them in the context of their use, maximizing the ability to both recall and apply those concepts as they move back into the work world. Students develop the skills (communication, collaboration, teamwork) and the personal characteristics (initiative, creativity, personal responsibility) that have become requisite for success. Students develop a high level of comfort with information technology as they regularly access information through the resources of the internet, collaborate electronically over time and space, and develop and make professional-level computer-driven presentations.

The program centers around some 8-12 major projects. These projects tend to be large macro problems that address business holistically. Each project contains multiple smaller problems that students must address to managing the total learning experience. Students construct their knowledge of business practices by working their way through the problems. Student learning is aided by the ability to access appropriate content on a just-in-time basis. Students learn content at a time when it will be useful to them in their management of the learning problems. While some of the problems are individual in nature, most of them are approached by collaborative learning groups.

While focusing on more macro problems and working with larger groups, the action-learning process used is a derivative of Reiterative Problem-Based Learning, which was developed by Howard Barrows (Barrows, 1985), and follows closely the concepts of cognitive constructivism (Savery and Duffy, 1994) and cognitive apprenticeship (Collins et. al., 1990).

3. The Action-Learning Process

In the action-learning process, students are presented with an ill-structured problem/situation without the benefit of prior preparation. They are challenged to frame the problem and decide upon action to be taken. Problems/situations may be presented in a number of different formats. Some are elaborate simulations of companies and industries while others are extended "Harvard-type" cases. Some are current situations reported in the business press while still others are real-life situations presented by cooperating companies. (This sections borrows heavily from Stinson, 1990.)

During the initial discussion of the problem, students are challenged to evaluate the knowledge they already have that relates to the problem/situation and to identify the knowledge they will need to acquire through inquiry, research, and self-directed study. A faculty tutor keeps the students on process, not by giving information or judgments but by asking questions. The first phase ends when students have committed themselves to the nature of the problem and how it is to be managed and have identified the areas they are going to study and the resources they plan to use in the study.

During the first phase, students will have 1) set learning objectives, 2) framed the problem, 3) developed hypotheses about action based on present knowledge, 4) noted actual knowledge they possess, 5) identified information needed, and 6) identified potential information sources. They are then released for a period of inquiry, research, and self-directed study.

At the beginning of the next iteration, students are asked to critique the resources they used to obtain information. They then address the problem/situation again using the knowledge and skill they obtained through their research. For a second time they frame the problem and develop hypotheses about action to be taken.

Students may have enough knowledge and skill to make a decision at this point, or they may raise additional learning issues that should be addressed before action is taken. The number of iterations necessary depends on the complexity of the problem/situation and the associated learning objectives.

As the final step in the process (intermittently during longer processes) students are asked to verbalize and synthesize what they have learned. Because so much of the learning is associated with problem solving, students may not be consciously aware of all they have learned. Further, they have developed their knowledge within a particular context. Students thus need to make their learning explicit and decontextualize their knowledge so that it can be used in a variety of settings.

Note that there are many variations possible. Students can work on problem/situations individually or in teams. Problem/situations can be rather simple (requiring only a short time to complete) or complex (requiring a whole quarter or semester). Students may end the process with a formal presentation of findings and recommendations to a panel of executives, or with a general group discussion which produces no single solution. These are only a few examples of numerous possibilities.

4. The Information Technology System

The OUMBA program fully incorporates and is dependent upon information technology. Home base is an "information-age workroom" totally dedicated to the program. Available in the workroom is a set of workstations on a local area network with a dedicated network server with dial-in capability. This server is connected to a wide area network and the Internet. This provides the capability to do real-time conferencing, collaborative writing, seamless file sharing, and E-mail, internally on the LAN and externally with our worldwide partners. Lotus Notes provides the backbone of the system. The standard software is Microsoft office. All students are expected to have access to a computer and, if they want to use the dial-in capability, a modem. The computer may use a Macintosh or Windows operating system.

Students have access to external data bases (Mead Data Central, OCLC, World Wide Web) and the ability to transfer electronic copies of major business magazines and newspapers to local data bases. Further, through the Internet, they can participate in global electronic conferences on topics of relevance to their study.

Learning modules have been established to support learning in the program. We are in the process of developing HyperMedia data bases and learning systems, including electronic copy of textual material, to support all learning modules. As developed, these are located on the local area network server.

The Ohio University MBA is also provided in a part-time format at locations 50 - 80 miles from our home campus for job-bound individuals. The part-time programs normally follows a Friday evening Saturday morning format, with meetings being held on the average of six times per quarter.

These part-time programs are also enabled by information technology. All part-time students have an address on the Ohio University MBA information network. They dial into the network on a toll-free 800 line. As with the full-time program, part-time students and faculty communicate electronically. Notices are given and calendars maintained electronically. Learning materials are provided electronically. Student teams collaborate electronically. Students present reports electronically.

5. The Use of Information Technology

Information technology is central to the delivery of the Ohio University MBA. It impacts both the efficiency and effectiveness of the learning system.

Throughout the program, students receive assignments from and communicate with faculty electronically. They search electronic data-bases for information. They prepare and submit reports electronically. The formal presentations they make to faculty and to business people evaluating their progress are electronic and computer-driven, frequently incorporating multi-media.

To prepare for and finalize their global alliances project (our MBA students team with students from a local university and complete a consulting project for a local business during a two-week visit to another country. In the past those countries have included Hungary, Malaysia, India, Thailand, and Mexico), students collaborate with their in-country partners electronically before they arrive to work together, and after returning to the states they continue their collaboration to complete the project. We expect to move into the use of teleconferencing as soon as it becomes economically feasible.

While all of these uses of information technology are important, the greatest potential is in our recent incorporation of information technology to enable group collaboration, and in the ability to search electronic data bases for information. During the program, most learning problems are approached in learning groups. Historically, this required that students meet face-to-face and share information related to learning issues and information related to the problem being addressed. Further, students needed to discuss their individual analysis and reach decisions regarding group positions.

Although students participated in team building and were trained in group decision making, most of their meetings were terribly inefficient. The meetings required that individuals come together at the same time in the same place (this was particularly difficult for part-time students). Further, the meetings normally involved start-up, wind-down and considerable social content.

While not eliminating face-to-face meetings totally, the use of Lotus Notes significantly reduces the amount of time collaboration is required. Notes "conferences" are established for each problem for each learning group. Within each major "conference" separate collaboration conferences are established. Typically these include:

(1) <u>A learning issues conference.</u> As learning issues are defined, they are stated as questions. As students find information and draw conclusions related to the learning issues they make entries in the conference. These are reviewed and comments can be expressed by all members of the learning group. Faculty members have total access to these conferences. These entries therefor become another source of evaluation of student learning.

(2) <u>A data conference.</u> As students determine what they need to know to manage a learning problem (information related to the specifics of the problem), the data needs are stated as questions in the conference. As individual students find information related to the data needs, they enter it into the conference where it is accessible by all members of the learning group.

(3) <u>An action conference.</u> In this conference, students express their conclusions about what should be done to manage the learning problem. Through this conference, students dialogue and start to approach conclusions about action related to the problem. Students also start development of reports and presentations in this conference. Faculty members review entries in this conference as another mean of evaluating student competence.

In addition, there are some ongoing conferences that are open to all faculty and students in all our MBA programs. These include:

(4) <u>A general interest conference.</u> In this conference students and faculty place information that is not directly related to the problem under study, but is related to the overall educational outcomes of the program. This includes information on, or reactions to, current business affairs, recent articles or books, good sources of information on the Internet, etc.

(5) <u>Cafe OU.</u> This conference, which was copied from NYU's Virtual College, is an informal chat area.

Bibliographies and annotated bibliographies are maintained in the Library portion of Lotus Notes. In addition, digital copies of some articles and news reports are also retained.

Most research, however, is done through the data bases available on the Internet and on local networks (OCLC, Nexus, Ohiolink). Both effectiveness and efficiency are enhanced via such access. Using these electronic sources, students access information that would be less available using traditional library sources (effectiveness), and they are able to access the information more rapidly (efficiency). Further, the process of abstracting digitally is much more efficient than reading hard copy, taking notes, and typing the notes into the system.

While central to the learning system, use of the information technology requires some adjustment. Initially, many students (and most faculty) are uncomfortable using electronic collaboration. With reasonable training and supported experience, a majority of individuals find using such means extremely helpful. They are able to make their inputs and express their reactions at a time and place most convenient to them. People who are sometimes reticent to speak at a group meeting, frequently find it easier to share ideas and opinions electronically. Individuals who have a tendency to talk off-the-cuff at group sessions, tend to think through comments more thoroughly before entering them into the system. Further, the tendency to "add noise to the system" is discouraged by less than positive feedback from peers who have to spend time looking at meaningless material.

Some skeptics initially expressed a concern that use of the information technology would somehow dehumanize the program. This has not been, however, the general perception. Students and faculty know, see, and still occasionally meet with their collaborators. Further, as they become more familiar with the use of information technology, people generally start to express their own personalities and become better adept at perceiving the personalities of others.

Since we are very early in the implementation of the information technology system, our conclusions should be viewed as hypotheses rather than facts. Our initial experience, however, suggests that the use of information technology not only enables, but substantially enriches our MBA program.

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A Framework of Hypertextual Vocabulary Support for Collaborative Learning

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Abstract

This article proposes a framework for designing support systems to enhance communications in collaborative learning activities using computer networks. Based on models of situated cognition and learning and research findings on vocabulary knowledge and learning, the importance of contextual information (including situational meanings and actual usage in discourse community) and hypertextual presentation of such information is emphasized. Two projects implementing this framework are described. The Language Mediation Assistant is a hypertextual system designed to help novice participants or those with limited language abilities to become involved in network-based projects. It provides contextual meanings and actual message texts from the projects hypertextually to help learners understand the meanings and usage of words in particular domains or in particular communities. Impact! Online is a project to provide ESL learners with an integrated language learning environment for reading, writing and vocabulary. News articles with hypertextual vocabulary aid and a mailing list for discussions on news topics are the core of this project. In these two projects, it has been observed that the framework of hypertextual situational support for vocabulary understanding is useful in computer network-based learning activities, especially with students using foreign language in communication.

Keywords — Hypertext, vocabulary, network-based collaborative learning.

1. Introduction

It has been demonstrated that computer networks can provide ideal environments for collaborative learning in many areas, including science, social studies, writing, foreign languages, and teacher education. Among advantages of using computer networks in education is a potential of including a variety of people in collaborative learning activities. Interactions and collaborations among learners from different backgrounds and between novices and experts are important elements in network-based collaborative learning. But it is not always easy to get people with different backgrounds and/or different perspectives involved in interactions effectively. One issue is that newcomers to a particular community of interactions have difficulties in comprehending the vocabulary used there. Also, with the growth of a potential of getting a wider variety of learners around the globe involved in particular learning activities though computer networks, it is becoming a more and more important issue how to support participants who use a second or foreign language. In the first part of this paper, I propose a framework for designing hypertextual vocabulary support systems to help learners to participate in collaborative network-based learning activities. In the second part, I describe two projects implementing this framework.

2. Framework of Vocabulary Support

In this section, I discuss two essential aspects for designing vocabulary support systems for collaborative learning activities: situatedness and complexity of word meanings. Before discussing these two concepts, I will first discuss the limitation of dictionaries as a means of vocabulary support for learning activities.

2.1. Limitation of dictionaries

When students encounter words whose meanings they are unfamiliar with, they are usually encouraged to consult with dictionaries to check the meanings of the words. Dictionaries are thought to be the most useful and reliable information source about word meanings. But the kind of roles dictionaries play in vocabulary comprehension and acquisition are questionable when we consider the research findings about learning of word meanings.

Miller and Gildea [5] reported that fifth and sixth grade children who had been given dictionary definitions of unfamiliar words generated many incorrect sentences containing those words because of the inaccurate understandings of the word meanings. Scott and

Nagy [6] showed that the children's failure to appreciate the overall structure of the definition was observed even when they were given unconventional, more explanatory formats of definitions. McKeown [4] analyzed conventional dictionary definitions and found major problems with them. Based on the analyses she revised dictionary definitions and examined the effects of the revised definitions. The result indicated that the revised definitions went a long way toward capturing the essence of the word meanings from dictionary definitions, but still the subjects given revised definitions made many errors.

These studies show a limitation of dictionary definitions as a tool to help learners to comprehend meanings of unfamiliar words. There are two important reasons for this limitation. One is that dictionary definitions are abstract in the sense that they are extracted from the contexts and situations in which those words are actually used. The second point is that word meanings are not what we can specify as necessary and sufficient definitions and that knowledge of word meanings should be regarded as complex and ill-structured one. In the next two sections, I discuss these two points and suggest a framework for designing effective tools for vocabulary supports.

2.2. Contextual and situated support for vocabulary understanding and learning

Word meanings depend highly on situations and social interactions and can not be totally captured by definitions [2]. In order to learn word meanings so that learners can use them in actual situations instead of just retaining them as inert knowledge, it is important to place them in situations of use.

Jargon words and acronyms are good examples of demonstrating the importance of situations in word meanings. They are shared with people only in certain communities and not understandable without being involved in those communities and knowing their vocabularies and discourses.

Many words have different meanings according to domains and communities of discourse. For example, when we are talking about spaceships, the most likely meaning of the word "gravity" would be different from when we are talking about poetry.

Almost any word has more or less similar features. One difficulty for learners is that it is often hard for them to realize that certain words are used in special meanings or in special ways in the community. To help students to comprehend verbal interactions and to get involved in communication effectively, it is essential to provide sufficient clues to the meanings and usage which are used in specific contexts and situations. Useful information for this purpose should include descriptions of meanings used in specific contexts and actual sentences and texts containing those words used in them.

2.3. Hypertextual support for vocabulary understanding and learning

A meta-analysis of research on vocabulary instruction [8] indicated that "the methods that did appear to produce the highest effect on comprehension and vocabulary measures were methods that included both definitional and contextual information about each to-be-learned word (or "mixed" methods)." The reason why we need multiple information sources in learning word meanings is that knowledge of word meanings is not so simple that we can acquire them just by being given simple information such as definitions or contextual clues only. To "truly know the meaning of a word is to possess complex and ill-structured knowledge" [1]. As they suggested based on Spiro and his colleagues' studies (e.g. [7]), one aspect of ill-structuredness is the contextual interaction of concepts. The meaning of a sentence is not a simple compositional function of the core meanings of individual words, and in order for learners to understand sentence meanings, they have to have complex knowledge beyond simple core meanings which dictionary definitions provide. Also, in an ill-structured domain, knowledge of the domain can not be reduced to a single generalization or organizational scheme. Complex structures of related word meanings can be characterized exactly as this kind of case.

Considering the complexity and ill-structuredness of knowledge of word meanings, it is important to provide learners with multiple sources of information nonlinearly and nonuniformly to help them gain sufficient information about word meanings in a way which allows them to acquire usable and applicable knowledge about the words. Hypertext systems are ideal for providing multiple information in this way.

Information relevant to word meanings include "definitions" of the words showing general and crystallized essence of the meanings, example sentences and texts showing in what contexts those words are used, and related words including synonyms, antonyms, derivatives, and so on. Even though the dictionary-type of word definitions have limitations as discussed above, they can be useful information about clues to some aspects of word meanings. Knowledge about concrete examples about word usage should be important parts of knowledge about word meanings [1].

Hypertextual systems enable us to provide learners with this variety of information in a way that learners can obtain necessary information in their reading. Not only do hypertexts show different types of information, but also learners can get such information interconnectedly.

3. Two Applications of the Framework

This section describes two examples of instantiating the framework described above in designing collaborative learning environments. The first one, the Language Mediation Assistant, is a hypertextual system to help novice learners participate in network-based learning activities by giving vocabulary help. The second one, Impact! Online, is a hypermedia news reader for second language learners and less skilled readers which provides hypertextual support for learning and acquiring vocabulary.

3.1. The Language Mediation Assistant - Hypertextual vocabulary support for network communications

The Language Mediation Assistant is a hypertextual vocabulary support system to help novice participants and those with limited language abilities to get involved in ongoing network-based learning projects [10].

It is sometimes difficult for newcomers to ongoing projects to participate in the discussions already going on. One major source of difficulty such novice participants often face is the lack of sufficient knowledge about vocabulary used in the community. In the process of communication within a particular community, some words often come to have specific meanings, having particular connotations. Without knowing how such words are used in the community, participants may have difficulties in understanding what the people there really mean.

In addition to the problem of special meanings, those participants who use a second or foreign languages to communicate in network-based projects often suffer from lack of sufficient vocabulary knowledge. Even when they have learned general or abstract meanings of words which they have been taught in second/foreign language classes, they often have difficulties in figuring out what the words mean in particular contexts at hand.

Considering these situations, it is quite important to develop a tool to support these participants' understanding of the ongoing communications in network-based projects. This section describes a hypertextual vocabulary support system, named the Language Mediation Assistant (LAMEA), created by using HyperCard on Macintosh computers.

The LAMEA stack consists of two different kinds of cards, word information cards and message cards. A LAMEA stack contains actual messages exchanged in network-based projects in a specific domain and information about important and/or difficult words used in them.

Message Card. Each message card has a message text on it. Those words with information included in the stack in the form of word information cards are highlighted in the text. When users click on one of the highlighted words, a small box appears near the word which show the meanings of the word. If they want to get more information about the word, they can look at the word information card for that word by clicking on the button "More Information." As described below, on a word information card, users can see not just meanings but also look at a list of related words and a list of other messages containing that word. By clicking on an item in these lists, learners can access to more information about the word to understand what meanings it has and in what way it is used in messages exchanged in communication in the domain.

Word Information. Each word information card provides users with a variety of information about a word. It contains "*meanings*," "*related words*," and "*list of messages containing this word.*"

Related words include derivations, synonyms, antonyms, and so on. Those words which are highlighted have word information cards for them. If users click on a highlighted item in related words, they can look at the word information card for that word.

Users can read other messages which contain the particular word. If they click on an item in the *list of messages containing this word*, they can go to the message card for that message text, so that they can read the whole message as a context of use of that word.

Effects of this system in theunderstanding of word meanings in use. A pilot study was conducted to explore the effectiveness of this system in understanding and learning word meanings in communications. Messages exchanged in a newsgroup were used. Nonnative speakers of English who hadn't looked at the newsgroup before read articles in the newsgroup by using this system. It was found that readers used not only the meanings provided to difficult words but also information about related words and other messages containing unfamiliar words. Many subjects commented that they prefer this kind of non-linear system providing contextual information, rather than conventional dictionaries.

3.2. Impact! Online - An integrated learning environment for ESL learner's reading, writing and vocabulary

Impact! Online is a project of providing learners of English as a second/foreign language with an integrated learning environment for reading, vocabulary, and writing by using World Wide Web and an electronic mailing list [9]. The purpose of this project is to prepare an environment where ESL learners can read about and discuss current issues to improve their reading, writing and vocabulary skills. Two components of this project are hypertextual news articles with vocabulary help and a mailing list for learners to have discussions about topics introduced in the articles.

Hypertextual newsletter with vocabulary help. We have developed a hypertextual newsletter for ESL learners and placed it on an educational World Wide Web server. Each month, a few new articles on current national and international topics are added to our WWW server. Difficult words in each article have hypertextual links to explanations of those words.

By selecting unfamiliar words, readers can access information about those words. Explanations about words include meanings, related words, pronunciation, example sentences, and links to relevant information servers. The meanings provided are contextually appropriate ones, not general or abstract dictionary definitions. Related words and example sentences are provided on each word information screen. Difficult words in related words and example sentences have links to the word information screen on those words. From some word information screens, we are implementing links to actual messages exchanged in the mailing list, so that learners can access more contextual and authentic "example" sentences.

On-line discussion. Learners participating in this project can have opportunities of not just reading our newsletter articles with vocabulary help but also having discussions on topics related to the articles. By getting involved in discussions on specific topics provided by the articles, learners can practice applying the vocabulary knowledge they acquired when reading annotated newsletter articles to authentic communication situations.

Effects of the integrated learning environments with vocabulary help. The log showing which files learners accessed indicated that there are many accesses to word information files during the reading of articles. And not only do they access meanings in word information but they often get more information about related words and relevant background knowledge (provided in the form of links to other information servers on related topics). In the discussions on the mailing list, the ESL learners use many important words used in the news articles whose explanations are provided in word information screens, which indicates that they acquire those words correctly and in a way that they can actually use them in communications.

4. Conclusions

In this paper, I proposed a framework of vocabulary systems to support collaborative network-based learning. I emphasized contextuality and situatedness as well as hypertextuality. In the two projects described here, the effectiveness of this framework has been supported.

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Groupware for Developing Critical Discussion Skills

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Abstract

Increasingly, social and collaborative processes are seen as central to the development of thinking skills, including the skills of scientific thinking. With colleagues we have developed a software system (Belvedere) to support high-school science students in engaging in collaborative reasoning and argumentation. We discuss how Belvedere is designed to support students' collaborative processes, describe our formative evaluation studies, and provide examples of student sessions. Reflecting on students' interactions with Belvedere and each other, we then discuss the competencies and limitations of students in developing scientific argumentation and reasoning, as distinguished from and supported by their practice of everyday argumentation.

Keywords — interface design, groupware, scientific argumentation, collaborative learning.

1. Introduction

Scientific knowledge has an increasing dynamism in two senses: it changes and increases extremely rapidly, and it is thrust from the lab into the wider world and the public forum almost as rapidly. These trends place increasing demands on secondary school science education. Besides knowing key facts and concepts and particular procedures, it is important for today's students to understand the processes by which the claims of science are generated, evaluated, and revised. In addition to efforts being made to restructure what is taught, there are grounds to change how it is taught. In particular, some researchers and educators have recommended collaborative discussion for learning science concepts and reasoning [10, 11, 12, 14, 15, 20].

Towards this end, we are experimenting with a software environment called "Belvedere" for supporting students learning to engage in critical discussion of competing scientific theories. In this paper we discuss some issues in using computers to support collaborative dialogues. We draw on our work with students using Belvedere to illustrate both student competencies that facilitate their practice of collaborative discussion of theories and affordances to facilitate their progress in such practice.

2. An Experimental Argumentation Environment

Belvedere is an environment designed to support the practice of critical discussion in a range of collaborative paradigms. It can be used jointly by students who are physically close together to work simultaneously on a shared argument; by students to work on shared arguments at different times; and, a use we have not been testing, by students working simultaneously but remote from each other. Superficially, Belvedere is networked groupware for constructing representations of the logical and rhetorical relations within a debate. The interface appears similar to drawing program (Figure 1), but using it feels more like assembling components into desired configurations. However, the utility of Belvedere's representations lies in the stimulation and coordination of discourse that takes place external to the representations themselves, as much as in their modeling value. Belvedere differs from other computer systems for supporting argumentation [6, 9, 16] because it is designed to support students who may not have general skills of constructing arguments or specific knowledge of a domain. Thus the design of Belvedere addresses the cognitive and motivational requirements and limitations of these unpracticed beginners (discussed below). Belvedere differs from other systems for supporting students' discourse [13, 14] primarily in being designed to scaffold discourse about scientific theories and evidence.

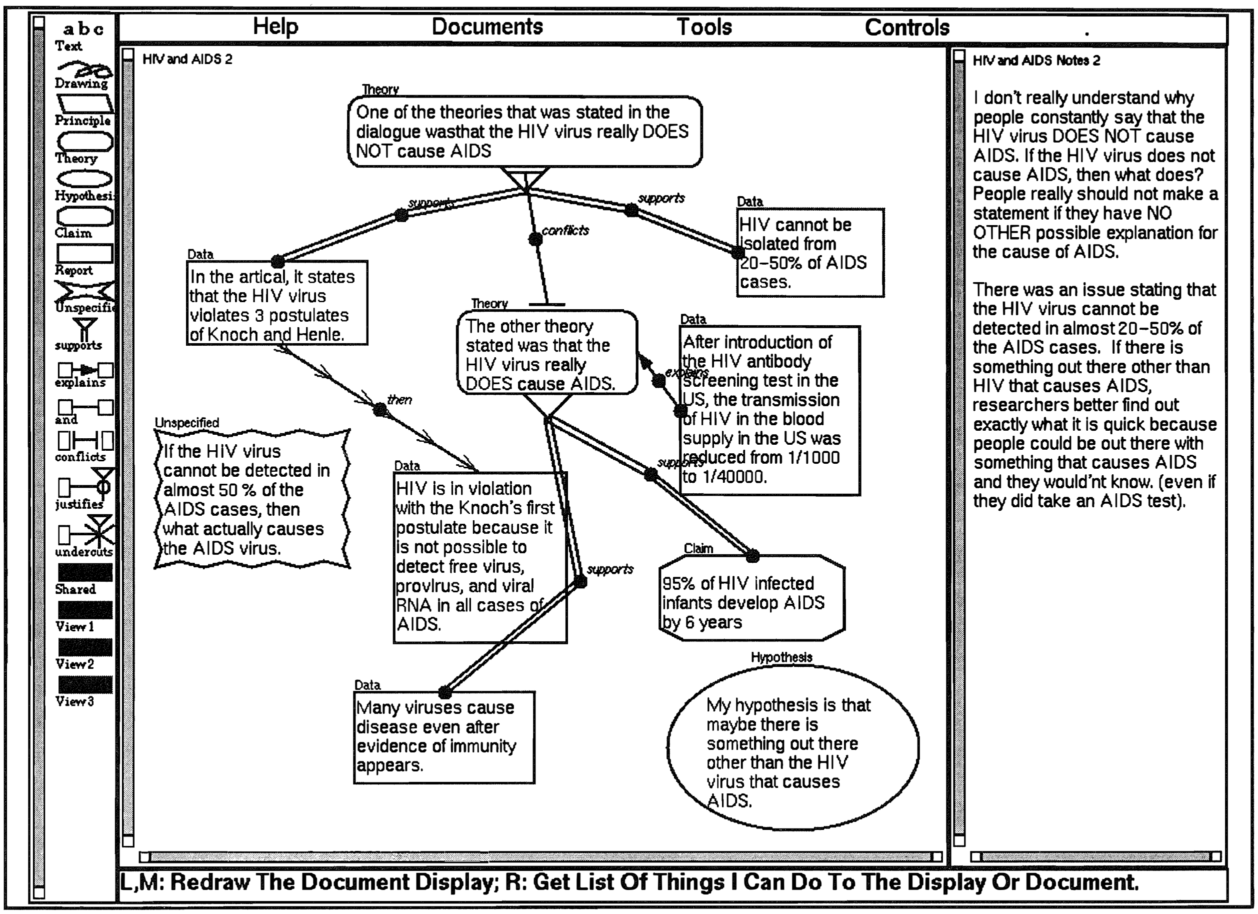


Figure 1. Diagram by Students on HIV and AIDS Issue.

2.1. Supporting Participation in Critical Discussion

After motivating the design in terms of how software tool can facilitate students' participation in critical discussion of science issues, we give some detailed comments on the design.

Reifying the Abstract Relationships Implicit in Scientific Theories and Arguments. Part of expertise in a domain is the ability to represent situations in terms of deep features or structures that are useful for solving problems in the domain [4, 5, 7]. Belvedere provides students with concrete forms for representing the abstract components and relationships of theories and related arguments. Ideas and relationships are represented as objects that can be pointed to, linked to other objects, and discussed.

Motivating by Shared Activity. Small-group work and the production of documents that will be used by others can provide peer motivation and a sense of authentic activity that teacher- and evaluation-centered work may not provide [2, 14, 15, 20]. To support small group collaboration while allowing each student equal opportunity for input, Belvedere is networked so that students can work concurrently on the same diagram. The reified arguments enable students to jointly focus on and discuss the same claim, simultaneously and independently address different points, and switch between joint and independent work without losing track of the discussion.

Directing Attention to the Important Issues in a Complex Debate. Argumentation diagrams can help students identify ways in which further contributions can be made to the argument [16, 17]. As the students build an argument, they can request advice. The automated advisor helps students focus on particular aspects of a complex issue by suggesting ways in which their diagrams can be extended or improved [18]. The advisor highlights objects in the diagram as possibly needing attention and offers hints based on principles such as consistency, empirical support, maximizing a theory's coverage, and considering alternative theories.

Providing Knowledge Resources. Belvedere provides facilities for authoring on-line knowledge resources that can be accessed and copied by students. Using these facilities we have authored modest collections of information in several scientific fields. Recently, Arthur Nunes has extended Belvedere to serve as a World Wide Web browser, enabling authors to use existing HTML tools.

2.2. Selected Design Details

Belvedere is implemented in the Common Lisp Interface Manager and ISI's LOOM, and runs in both Lucid Common Lisp on Decstations and Macintosh Common Lisp. We describe several aspects of the implementation briefly here.

The Graphical Language. The graphical forms we provide for argument representation are loosely based on the analysis developed by the philosopher Stephen Toulmin [19]. The representations are specialized for scientific argumentation by providing shapes for different types and components of arguments, negative as well as positive links, and enclosure and multiple linkages to accommodate complex arguments (see figure 1). A special "undefined" shape is provided for use when the epistemological status of a statement is not obvious or agreed upon. Different kinds of links between shapes represent different logical and rhetorical relations between the different statements. Colors are available to distinguish different viewpoints such as different theories or the contribution of each participant. Line thickness can be changed to express importance. Students can type text in to their diagrams or copy and paste excerpts from on-line or World-Wide Web documents. A primitive freehand drawing tool is also provided to enable participants to extend the representational repertory. Labels can be displayed for either shapes or links or both, and students can optionally change the labels and the shapes.

The Display. Belvedere is a symbol system for the expression of logical and rhetorical relations within a debate. We wanted participants to focus cognitive effort on the debate rather than on learning to use the program. Thus we made the interface look familiar by using command and icon layouts similar to those of typical drawing programs. We help maintain the students' focus on their understanding of the theories and controversies, rather than on every graphical detail of their diagrams, by automating some of the secondary aspects of the work. For example, graphical shapes are created with a default size, and resize themselves to fit their contents. When an object is moved, its links follow it to retain the logical connection. Other tools such as the automated advisor provide further relevant functionality not available in drawing programs.

Management of Concurrent Activity. In our initial studies with students sharing a single machine, some students appeared frustrated when limited to mouse operation while a partner dominated the input by typing on the keyboard. To avoid censorship based on who owns the input devices, we enable separate machines to display a shared document. Thus students can work concurrently on a shared diagram. Additional functionalities were required to manage this so as to minimize unnecessary redisplay overhead and maximize the students' focus on cognitive tasks. They should not be distracted by a constantly changing screen while they are thinking. Also, participants must not be able to operate on the same object simultaneously. We therefore "lock" an object as soon as a participant starts to use it. When it is locked, other users cannot modify it. Nor do they see the object changing: this would be annoying to someone pursuing their own thoughts, and require excess redisplay overhead. When the participant is finished editing and releases the lock, a redisplay interrupt is sent to other participants' applications. This interrupt is delayed by any applications in which another participant is editing, to avoid unexpected change of the context of their work.

3. Formative Evaluations

We discuss our formative evaluations to convey our experiences with both the advantages and dangers of collaborative learning processes.

Initial formative evaluation included several task scenarios tried with 8 paid subjects, ages 12 to 15, working alone or in pairs, in 17 different 2-hour sessions in our laboratory. We ran three sets of laboratory studies, starting with an early prototype.

In the first set we were primarily concerned with the usability of the interface and the suitability of the diagrammatic representation. Individual students were briefly introduced to the representation and were acquainted with the interface. Then they were given a text presenting a scientific theory about the origins of mountains and asked to use Belvedere to show the ideas in the text. Considerable revision of interface details resulted from these sessions.

In the second set of studies, students from the previous studies worked in pairs using one computer. Each pair was asked to attempt to resolve an apparent anomaly for the Darwinian theory of adaptive radiation. (According to this theory, the unique species of the Galapagos islands separated on the islands in response to opportunities there. Molecular-biological dating indicates that the marine and land species of iguanas on the Galapagos diverged from a common ancestor about 12 million years ago, but radioisotope dating of rock gives an age of only 3 million years for the islands [3].) The initial conflict was presented in both textual and graphical forms. Students could call up texts from a modest database of small pieces of information, most of which was relevant to the problem, although not always in obvious ways. We were encouraged by the amount of discussion we saw in some pairs. However, in some cases the student who obtained the keyboard dominated and censored the other student's proposals for the diagram.

These observations motivated redesign of Belvedere for the third set of studies, identical to the second except that the students worked on individual computers networked together and located side by side (close enough to see and point to each other's displays). The monitors displayed a shared drawing space and a display in which each of the students could bring up texts from the database. This networked configuration was tested with two pairs of students in the laboratory, and subsequently with many more in the schools.

At this point we were satisfied that the prototype environment had potential value for students, and we began studying how 10th grade students and their science teachers might learn and use Belvedere in a classroom. The school is an urban school in a low-SES neighborhood. Its students have access to a computer lab and thus most of the students were familiar with a low-end Macintosh and mouse. One activity of the teachers and students during the time we observed them was preparation for a local science fair. This gave us the opportunity to observe some students' presentations of library research and later of project findings. Our informal impressions were consistent with others' ethnographic observation that discussion was teacher-initiated and teacher-centered, and that students' talk was social or task-related rather than conceptual [10].

One of the teachers suggested that we use a debate she had recently seen on an electronic discussion group: whether HIV is the cause of AIDS. Using a published summary of the scientific sources of the debate [1, 8], we developed a small database for theories of the cause of AIDS. Eight sessions were conducted in which two to three students worked on shared documents from their own machines, but sitting close enough to talk and see each other's displays. Figure 1 shows the argument diagram produced by one pair of students after two half-hour sessions (which included the time needed to learn to use the Belvedere system for the first time). Note that it includes not only the argument against causation but also some beginnings of rebuttal to it.

4. Students' Competencies and Needs

Most of the students in the collaborative studies created nodes, filled them with text (either typed in or copied) and linked them. Only one student completely misunderstood the representation, attempting to use Belvedere as a pictorial rather than a symbolic drawing program. The students in the classroom seemed to have clear opinions on the AIDS issue. Many students in both the lab and the classroom studies brought in knowledge and personal experiences from outside the textual materials provided to them. Most students were able to incorporate several points of the debate into their diagrams, drawing on the printed texts and/or the on-line information provided them, even in the short span of a class period. When prompted, most students were able to discuss what they thought about various aspects of the two positions, even if they were unable or unwilling to incorporate their thoughts into a Belvedere pane. Apart from collaborative processes to be discussed, difficulties arose primarily from problems with the software, limited screen size, and lack of clarity concerning the task posed to them.

4.1. Generating Multiple Hypotheses

One of the potential strengths of collaborative work is that alternate hypotheses and multiple perspectives may be considered. Consistent with this claim, subjects in dyads or triads usually generated several hypotheses (in contrast to observed science-fair monological presentations). For example, one dyad generated these hypotheses for the Galapagos problem: (1) the dating of the species' divergence may be wrong; (2) the islands may have been dated using younger surface rocks formed during volcanism subsequent to the initial formation of the island; (3) "the Galapagos islands may have moved near to another land mass where the iguanas were found" (subsequently this student asked about tectonic plate movement); and (4) when the Galapagos were forming, another island near them had the two species on it already. In an HIV and AIDS session (not pictured), discussion was focusing on discrepancies between the time during which HIV is most active, the onset of immunity, and the onset of AIDS symptoms. One student suggested that two disease processes may be involved; another suggested that HIV may not be the cause of AIDS but enables contracting AIDS. Typically, more verbal proposals were made than were entered into the diagram.

4.2. Peer Coaching

Students also complemented each other with background knowledge, or by spontaneously explaining the use of the interface or the meaning of the terms to each other. For example, a student wondered what shape to use for the violation of the 2 postulates of Koch and Henle in Figure 1: "This would be like data, I think so, or a claim, would it be a claim or data?" Her partner replied: "Claim. Cause they don't have no real hard evidence, go ahead, claim. I mean who cares, who cares what they say? Claim." However, a peer's argument can lack authority: she chose "data."

4.3. Conceptual Change

When conflicting hypotheses were proposed, some groups engaged in a dialectic tension between challenges and resistance to change that provides a potential microcosm of scientific debate. For example, consider the dialogue of a Galapagos-problem dyad, selected portions of which are reproduced in Table 1. (The corresponding diagram is shown in Figure 2. The students chose pseudonyms.) Initially (3:38 of Table 1) Mo proposes that the two species came separately to the islands by floating or swimming. Emin then begins to encounter evidence that leads her to question this idea (3:57, 4:01 and 4:28), but Mo rather consistently dismisses it in order to maintain her reigning hypothesis. Later, we presented them with four alternate hypotheses to consider. Subsequently (4:52), Emin gently challenges Mo's conception, apparently on the basis of parsimony. By the end of the session (5:07), Mo gives up her former hypothesis and chooses one of the new

Table 1. Selections from Dialogue Between "Emin" and "Mo," Galapagos Iguana Anomaly

[3:38]

Mo: Do you want to put anything in, how ... we could always put something ... like, land animals, it says they could, like, travel on rafts of vegetation or on logs.... Do you want to put that in, because that's a way that they could've both migrated to the islands.

Emin: OK.

[3:57]

Emin: If there were no marine iguanas anywhere in the world except for the Galapagos, wouldn't that mean that they had developed from the land iguanas, and not from any other ... the land-?

Mo: Um, well, they could've, but I think what, uhh-

Emin: Or they would've found, they might've found a climate, like, any other climate-

Mo: It says these two species separated about 12 million years ago, but maybe, like, and the islands weren't around then, so probably what happened is the marine iguanas died out by then everywhere else. Like, not by then, but by the time they got to the Galapagos islands they died off everywhere else, maybe. Does that make sense?

Emin: Yeah. So, do you want to put this in there, and then ... type what you just said? That they probably died out by then.

[4:01]

Mo: OK, now let me see what this says ... *[read text of document indicating that marine iguanas do not swim for long distances.]* ... But that wasn't a very long distance so that doesn't count. Because Ecuador to-

Emin: So the land iguanas probably developed from the marine iguanas, because-

Mo: Well, yeah, but they also, see, that's why we put that, they can go on the rafts and-

Emin: How did they get there in the first place? On the vegetation or whatever?

Mo: Yeah, the rafts or on logs.

Emin: Hey, look; the marine iguanas don't breathe under water.

Mo: They don't breathe under water?

Emin: They hold their breath.

Mo: Well, that's OK. That doesn't matter.

Emin: Well, it shows that they probably evolved from the land.

Mo: No, because they can always, um, come up if they're swimming under water ... *[examining map of location of the Galapagos relative to South America]* 600 miles; well ... that's still not too far ... It looks close on the map.

4:28]

Emin *[upon opening document that states that no marine iguana fossils have been found anywhere in the world other than the Galapagos]*: Uh-oh. *[Emin points out contents to Mo; Mo groans]*

[4:52]

Emin: Look; the second one [points in R-pane], it kind of goes with these two top ones *[points to #4 and 5]*, that they developed from ordinary land ones, because no fossils had been found, and no marine ones are anywhere else.

Mo: Umm ... That could be connected to either this one, right here *[mouses over #c]*, or it could be connected to these two *[mouses over #4 and 5]*, I think. I think either way you could connect it. Because you could say that because they separated here *[mousing over #c]*, they could've, umm, the marine could have died out, the marine iguanas, and then they could have, like, been reborn almost.

Emin: Why would they die out?

Mo: I don't know. *[laughs]* Somehow they could have died...

Emin: Died out on the islands? Because there were no fossils found anywhere else in the world.

Mo: Yeah ... Well, they could've died out when those islands weren't around then. So they probably - They could've just died out wherever they were, and then, umm, the land iguanas, when they got to the islands, they, then in 2-3 million years, the marine iguanas developed from them.

Emin: But, you're saying that they died- that they were living someplace else and they died, and the land iguanas went to the Galapagos islands, and new marine iguanas were born again?

Mo: Because there's no proof that says that the original marine iguanas are the same as the ones that are right now. But I don't know-

Emin: Yeah, I see what you mean.

Emin: *[A few minutes later]* OK, but if they migrated *separately*, how did the *marine* ones get there in the first place, if no fossils have been found elsewhere? They had to start out from someplace.

Mo: Oh. Well maybe they just haven't found any yet. [*Emin laughs]* The fossils are always beneath the water; maybe they just didn't, I'm sure it's hard to find fossils underneath the water.

Emin: They might've died on land. [*laughs]*

[5:07]

Emin: Well, I think the answer is that just the land iguanas came from South America, by floating vegetation or whatever, and a subspecies developed off them which were the marine iguanas, since their fossils weren't found anywhere else.

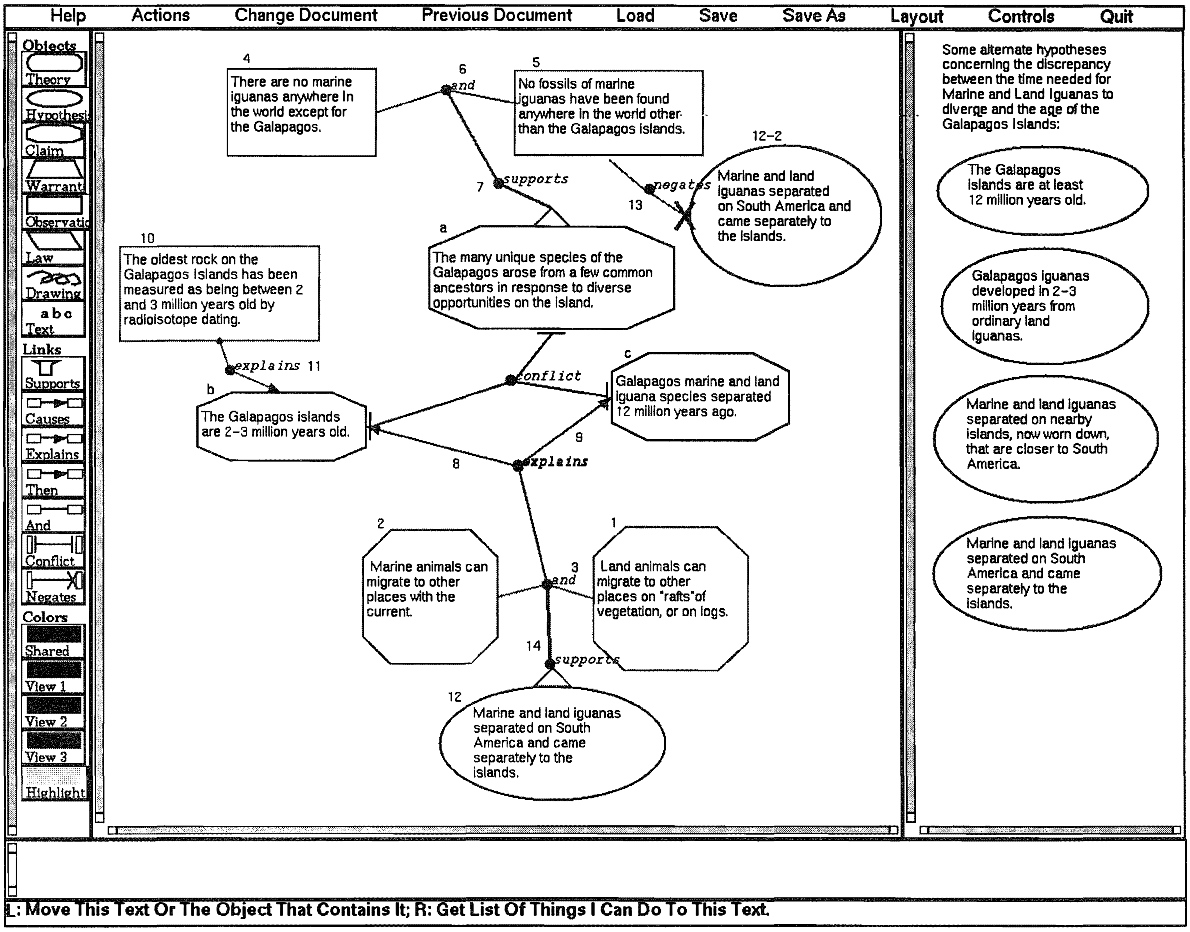
Mo: I sort of agree with these two *[points at bottom two ovals in R-pane]*, that the two kinds of iguanas separated on islands that are now worn down that are closer to South America, and then they both could have migrated to the Galapagos Islands, because marine animals- marine iguanas aren't found anywhere else, that would, like, explain that.

Emin: I'd like information on whether or not those islands, the worn-down islands ... if there were fossils and stuff-

Mo: Yeah, more on if, uhh-

Emin: ... other possibilities.

Mo: Where they've searched for fossils, too.



This session was conducted in an earlier version of Belvedere. The alternate hypotheses pictured were presented to them near the end of the session. Typically, only a portion of ideas and relationships discussed are captured in student diagrams (compare figure to Table 1).

Figure 2. Diagram by "Emin" and "Mo," Galapagos Iguana Anomaly.

ones. (The "worn-down islands" that she refers to are nearby sea-mounts, dated to be older than the Galapagos and bearing evidence of having once been above sea level.) While we cannot confidently identify the cause of Mo's change, we believe that dialogues such as this, with appropriate scaffolding and reflective follow-up, can provide the basis for personal experience of scientific dialectics.

4.4. Social Impediments to Learning

However, social processes do not always guarantee positive results. For example, in the first Galapagos-problem dyad, there was a subdued management struggle as one student wished to pursue a single line of argument and the other suggested that they should make a lot of hypotheses first. One student became frustrated when she suggested "maybe the dating is wrong," and her partner (in control of the keyboard) replied, "It can't be wrong, it's DNA." Even after we provided subsequent dyads with independent input devices, censoring persisted, albeit to a lesser degree. For example, Emin, was not always able to withstand Mo's confidence and be heard. At one point Emin justifiably challenges Mo, only to agree (in an unconvincing tone) a moment later, "I see what you mean" ([4:52] in Table 1). Thus, in an effort to be politely consensual throughout, a cooperative pair or group may fail to make the most of individual knowledge and judgment.

After persistently challenging Mo's conception that the marine and land iguanas separated elsewhere, Emin concluded that the species separated on the Galapagos ([5:07]), apparently forgetting the dating discrepancy posed at the outset. Her challenges to Mo indicate that she did not lack the ability to appreciate and address conflicts. Thus, even competent students may need help in keeping track of issues in a complex debate.

Finally, scientific argumentation is a specialized skill, and so requires an apprenticeship to practices not found in one's peer group. For example, look at the right-hand panel in Figure 1. It is common in everyday argumentation to ask critics to be constructive. As shown in the figure, one participant suggests that researchers should not criticize the theory that HIV causes AIDS unless they have a better explanation. Students cannot be expected to discover on their own that this criticism has less force in scientific argumentation: hypotheses must stand up to criticism whether or not alternatives exist.

5. Conclusions and Further Work

Our ongoing work is motivated by our observations concerning the need for apprenticeship to practices not found in peer groups, and tradeoffs in design of groupware for collaborative learning.

Scaffolding Scientific Argumentation Skills. We are currently pursuing several lines of inquiry into ways to encourage students' existing competencies while scaffolding learning of skills that are not found in everyday argumentation. An automated "advisor" gives advice concerning ways in which an argument can be extended or revised. Such advice is important for exposing students to standards of evaluation that may not exist in their peer groups. It is also expected to stimulate further inquiry when students have reached an impasse. The advisor is discussed further in [18]. Also, we are designing argumentation palettes (the menus of icons, see left side of Figure 1) for everyday and scientific argumentation. The palettes vary in granularity, distinctions available (e.g., whether "justifications" are included as a component type), and relationships emphasized (e.g., theory versus domain). We plan to use these palettes to effect transitions between everyday and scientific argument in a manner fitting students' emerging competencies and readiness to appreciate new distinctions. We also plan to experiment with rhetorical and topical ways of indexing information, the goal being to help students acquire appropriate information-seeking strategies.

Tradeoffs in the Design of Groupware for Learning. The emphasis on stimulating critical discussion complicates the criteria for interface design. Although we design to make it easy to construct diagrammatic representations of the dialectical aspects of science, we also design to stimulate external discourse that need not be recorded in the diagram. We have found that the latter goal can overrule the utility of features we would otherwise provide in support of the former. For example, statements in Belvedere are embedded in shapes that represent their epistemological status. Consequently, students using Belvedere often discuss the epistemological status of a statement before representing it in the diagram. An object can only have one shape at a time; therefore their discussion of the epistemological status cannot be part of the diagram. This might be viewed as a design flaw of the graphical language. However, it may be useful to force a decision prior to entry in the diagram precisely because it stimulates discussion towards making the decision.

Feedback on incoherent or weak constructions provides another example. If Belvedere were a tool for use by expert members of some community of practice, we could assume that users shared standard terminology and practice in argumentation. Incoherent links could be disallowed without explanation, and early notification of incoherent or weak patterns of links might enhance the users' efficiency as argument designers. However, students may have different feedback needs. They do not yet share the semantics of argumentation terminology, and immediate notification of incoherent or weak argument patterns could prevent students from engaging in processes of theory criticism and revision that are encountered in the real world.

Although unresolved, these issues illustrate the difference between local and systemic optimization of groupware for learning. Design to support discourse processes must transcend the representational environment of the software itself, even in software that specifically relies on the utility of on-line representations for discourse. The participants' discourse processes take place in the social environment as well as within the representational and computational resources provided by support software. Thus, the utility of software features should be evaluated in terms of how well they stimulate the right kind of activity in the total human-computer system, not merely in terms of support for local tasks. All of our efforts seek to uncover how productive discourse can be facilitated or stimulated by each feature of the interface and of the task posed to the students, and how we can design the interface and task to support a collaborative transition from everyday to scientific argumentation skills.

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Interaction-Level Support for Collaborative Learning: *AlgoBlock* — An Open Programming Language

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Abstract

In this paper, the role of computer-based educational tools is discussed from the standpoint of situated learning theory (e.g., Brown et al. 1988, Lave et al. 1991), which considers learning to be a process of enculturation in a community of practice (Lave et al. 1991). The authors propose, as one possibility, the role of computer-based educational tools as supporters of a "community of learners". "Community of learners" is a community maintained by "learners" who are trying to establish their identities in a certain community of practice. It works as an interface to full participation in the community of practice. Both facilitating interactions among learners and making links between activities within the community of learners and practices in the real world are crucial for supporting the community of learners. As the first step to this goal, the authors focus on interaction-level support of the community of learners, and mention AlgoBlock, a tangible programming language developed by the authors, as an example of computer-based educational tools for facilitating interactions among learners.

Keywords — Community of learners, Software Education, Open Tool, Situated Learning.

1. Situated Cognition and Education

The main claim of situated cognition is; "one's actions are interactively achieved through a relationship with the external world". The word "interactively", mentioned here, implies that one is not simply influenced by the external world. It is an interdependent relationship: the external world would appear as one attempt to participate in the world, and then the action would be formed by that world. The relation between one's action and the external world is inevitably mediated by "artifacts": tools, symbols, words, etc.. In other words, one's action is achieved as a result of interaction with the external world by utilizing some kinds of artifacts as a medium (Cole et al. 1980). It is important that the artifacts carry a history of some culture of practice, and they can be understood only when observed through that culture of practice which is creating and maintaining them. The artifacts are continuously reproduced in activities of the communities through works, and one consequently can "acknowledge" the meaning of artifacts through participation in the activities.

Given that one's action is considered to be achieved through utilizing artifacts as media, learning cannot be separable from artifacts. Furthermore, if artifacts cannot be dissociated from the practice of a community, learning should be considered to be a process of participating in a culture of practice (Brown et al. 1988). Thus learning is considered to be a process of enculturation. Based upon this idea, Lave et al. (1991) proposed a concept of legitimate peripheral participation, i.e., LPP. LPP is a learning principle in which one's learning is described as process of development of participation in a community that proceed gradually from peripheral to full.

2. Community of Learners as an Interface to Full Participation

In this section, the authors discuss how new community members become full participants of the community, based on the ethnographic investigation on learning of new staff nurses (Suzuki et al. 1994b). The new staff members assigned to the ward are first assigned to peripheral work such as resupplying articles on the nurse's cart and assisting with treatments provided by senior staff nurses. Through this process, they gradually learn medical terms and learn how to use nursing tools and they expand accessibility to their working environment, thus eventually they participate in the nursing community fully. This process is really LPP-like. Moreover, the authors would like to point out that establishing one's identity in nursing community is not easy experience. In this research, the authors observed a scene in which one of new staff members who failed to properly prepare a test was ridiculed and made fun of by senior nurses. Sometimes, involvement in the nursing community is very stressful to the new staff members. Furthermore, the authors found following report in an informal "circulating diary" which new staff members were circulating; "the senior nurses look like geniuses. I have no confidence that I can be like that in the future". Even if the new staff members were accepted warmly by the senior members, their participation would be still difficult because the nursing community is an unimaginable distant world for the new staff members and they are unable to see how to establish their own identities in it.

In such circumstances, the new staff members form their own community: community of new staff members, and help each other. Thus they overcome difficulties which occur in their practices. The new staff members are monitoring each other, paying attention to who has already experienced what, or who is going to experience what. Consequently, they ask other new staff members who have previously experienced some new procedures for help with these procedures. Those who have learned a new thing eagerly give the information to the other new staff members. They try to share their knowledge mutually with the others through making and circulating memos in which they record procedure of treatments and important numbers, e.g., time of a treatment, quantity of dose. They are also circulating an informal diary in which they write about their daily experience, including both vocational and private concerns, and they respond to the others' descriptions. This diary is one way to make their experiences shared.

Community of new nurses, which is a sub-community within the nursing community, is a "community of learners" through which its members are becoming regular staff members in the nursing community. When facing senior nurses, the new nurses feel overwhelmingly "incompetent". In such a circumstance, it is not easy for new nurses to establish their own identities and sense of competence. On the other hand, in their own community of new staff nurses, the new nurses can position each other as "a little more senior" and "a little more junior" in relation to each other. Therefore, it is easier for them to establish their identities in the relation. It is supposed that the new staff members establish their own positions within their junior community first, then they gradually establish their own position within the nursing community through using the community of learners as an interface to enter into the practicing community of nursing. Of course, it should not be forgotten that the new staff members' community can function as an interface toward the full participation in the nursing community only when the members of the community keep and share an intention to be nurses in their future.

The result of this investigation seems to suggest the possibility that, "places prepared for learning", e.g. schools, can be designed and used as an interface to see actual practice in the real society and to prepare people for entering into the community. The knowledge learned through the educational activities within the school, which is a socially closed community, can be used only within the school community. However, the school can be re-designed to be a place that becomes and is maintained as a community of learners aimed at practice in the real society.

3. CSCL Environment as an Interface Toward Practices

3.1. An educational tool which supports community of learners

If learning is the process of establishing a certain position in a community of practice, computer based educational tools have to be designed so that they support the learners' participation in a culture of practice. There might be many ways to do this, not just one. However, when focusing on a function of the learners' community as an interface toward the practicing culture, one direction for designing of the computer based educational tools can be drawn. It is educational tool for supporting a community of learners. The role of the tool should be to accelerate interaction among the members for forming, maintaining and reproducing the community of learners, and to support the linkage to the actual practicing world from the community of learners.

Two levels of design will be necessary for educational tools to support the community of learners. One is the interaction level design and the other is the social level design. The former is to design educational tools for accelerating the interaction among learners. For the community of learners would be generated, maintained, reproduced and transformed via the interaction among learners. The latter is to design the social settings which set up how the community of learners should be formed, and then link the activities of learners within the community to the outside world.

3.2. A designing for interaction-level support

In this discussion, the authors focus on the interaction level design, i.e., facilitation of the interaction among learners through the design of educational tools, and consider the necessary requirements for that purpose. One important design principle is to let the interaction among learners be controlled by natural rules. If unnatural rules, far from everyday life, are forced for interaction control, active interaction is not possible; thus, activities of the community of learners will be stagnated. In everyday life, one achieves interactions among members through utilizing eye lines and body movement and its positioning as resources of interaction control. Therefore, it is noteworthy that the interaction in the learning environment is facilitated through allowing learners to utilize these resources.

The eye lines display persons' intention socially. Goodwin (1981) showed, through a study of conversation, that human beings dynamically achieve interaction by monitoring the other person's eye lines mutually. In addition to eye lines, setting one's body toward a certain thing is also a social display of one's intention. Kendon(1990) presented the idea that there is space called transactional space around one's body. According to his idea, trying to fix one's body toward a certain object is equal to trying to set one's own transactional space upon the object. When people's transactional spaces are overlapped shared collaborative space is generated. Furthermore, Kendon introduced concept of "F-formation", which is a physical configuration of bodies that produce overlapping of transactional space. In such a way, eye lines and body movement and its positioning are important resources for social interaction

The other principle is to design the tool as an "open tool" (Hutchins 1990) which openly displays the process of collaborative work to the members. It allows members of collaborative work to monitor each other regarding what the other members are thinking and the present condition of the work. Thus, the conversation and discussion among members in the community are induced and overall performance in the community of learners as a functional system is heightened.

Here is an example of an open tool. In the previously mentioned investigation on learning of nurses, the authors found that nurses are utilizing a tool called "order bar" (Shiji-bou, in Japanese). It is a plastic marker which can be slipped between pages of the clinical records. It is placed there when the physician gives some order to the nurse. The length is arranged so it can be seen from outside even when the records are closed. By simply looking at the clinical records, the staff nurses can know if there are any orders by physicians or not. Upon completing the treatment ordered, the staff nurse who provided the treatment can take the bar out of the clinical records. The order bar functions as an open tool showing whether or not any orders are given by physicians to the whole staff and enabling the whole staff to monitor the status of task execution. The order bar functions as an open tool, but it is not only because of the physical reason that its length comes out of the clinical records. In the observation, the authors saw a scene in which one new staff nurse was blamed by a senior nurse for taking away a clinical record which had the order bar in it from a certain desk. The openness of the order bar is maintained by an unwritten arrangement shared among the staff nurses: clinical records with order bars have to be placed on the desk so that the whole staff can monitor the order bars. It is very important to notice that designing a tool as an open tool should essentially include not only designing the tool itself but also designing social settings in which the tool will be used.

4. AlgoBlock: A Tool for Collaborative Learning

4.1. The concept of AlgoBlock

Here, the authors introduce an educational tool: AlgoBlock (Suzuki et al. 1994a), which facilitates the interaction among learners. AlgoBlock (Fig. 1) is a program language which has an actual physical existence. Each tangible block is assigned a command of logo-like program language, and the program can be made by connecting those blocks to each other.

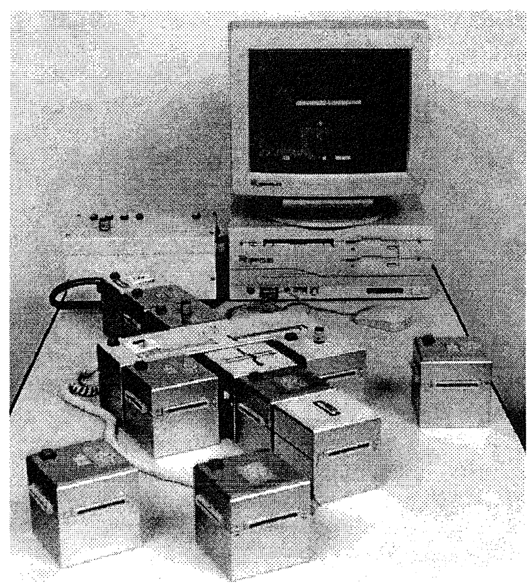

Figure 1. AlgoBlock: It is an open programming language.

The result of running the program is indicated on a CRT screen in the form of an animated submarine (Fig. 2). The age of expected use will be from higher year elementary school students to junior high school students. This tool was designed to allow learners to improve skills of problem solving through collaborative programming work.

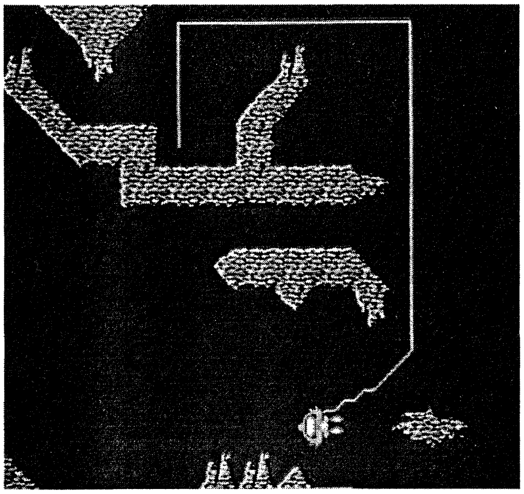

Figure 2. Screen design of AlgoBlock.

One can not suppose the existence of general skills of problem solving. Actually, human beings carry out a variety of problem solving activities in a variety of situations. The skills are strictly context dependent. One possible way of "problem solving education" would be to show students how real practitioners in a variety of fields are solving their real problems, and to give them opportunities to go through some parts of their practice. There are many practices worth seeing in terms of problem solving skills. The authors are focusing on the practice of programming because it is one of practices in which problem solving skills are considered to be very important. Thus, the authors are trying to make an educational environment in which the community of "programming learners" is created and learners can know how programmers solve problems, and they can simulate the practice of programmers. AlgoBlock was designed as a tool to give interaction-level support for the community of programming learners. In the following discussion, the authors will focus on how AlgoBlock facilitates interactions among learners.

As opposed to conventional programming which is done using a personal input device such as keyboard and mouse, making the process of programming difficult to share, AlgoBlock allows the process of programming to be open. By working on this tangible tool which can be shared in collaborative space, manipulations to the program are converted into external activities that can be observed as body movements and changes of body settings, and results of the manipulations are also easily grasped as change of configuration of the physical blocks (Fig. 3).

Therefore, children can monitor each other as to what kind of work the other group members are doing, what they are thinking and how the work is going. Moreover, doing the work against the physical blocks makes it easy to control the interaction by utilizing gaze, body movement and positioning as resources of communication. These features of AlgoBlock are expected to activate interaction among learners

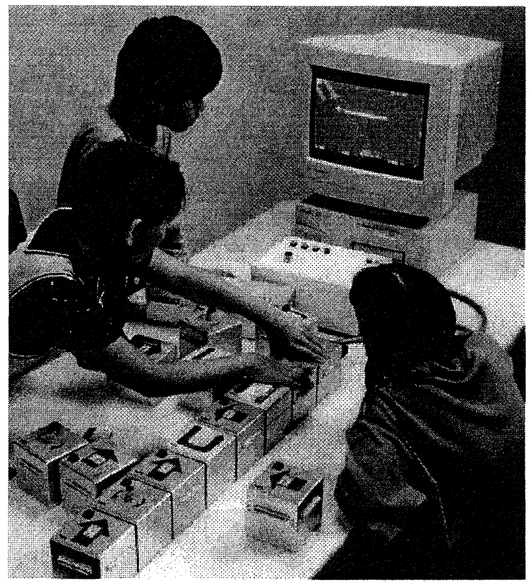

Figure 3. Collaborative work with AlgoBlock.

4.2. Evaluation experiment

The authors have carried out an evaluation experiment in which a group of three 12-year-old children engaged in group programming works using AlgoBlock. The purpose of this experiment was to see how AlgoBlock affects the interaction among learners. The children had no preceding experience in programming or manipulating computer based tools with the exception of video games. In the experiment, three tasks in which the children were required to move the submarine towards the goal were given after a 3-minutes introductory phase. In the introductory phase, they were instructed to observe the operations made by instructors for a while. Two instructors attended the session for the purpose of switching tasks and assisting children in case of system trouble. The instructors were encouraged to minimize interventions in children's works. Conversations and non-verbal actions during the experiment were videotaped.

Following is the setting of the experiment room: The command blocks and the controller, a personal computer, and a large size CRT monitor are placed on one table, and children are situated in a semicircle surrounding the command blocks on the table. Each child is given a chair, but is free to sit or not. There are five commands used: GO-FORWARD, GO-RIGHT, GO-LEFT, ROTATE, and LEG-FOLD. LEG-FOLD is a command to make the submarine fold its legs for landing. When the legs are folded, the submarine can jet to the right or left and then proceed direction of left or right. The controller is a device which connects the command blocks and the personal computer. When children push the start switch on the controller connection-information of blocks is sent to the personal computer to run the program.

Throughout the session, it was observed that the children interacted with each other vigorously, and they could operate AlgoBlock without difficulty after the 3 minutes of introduction phase, although it was the first experience for all children manipulating programming language.

4.2.1. A Fragment of conversation from the experiment

Following is a fragment of conversations and actions during the experimental session. The conversation is originally in Japanese. In this fragment, the following notations are used: " "=conversation, |=interrupted, { }=body movement, ()=notes by the authors, []=explanation number, /=indication of simultaneous utterance or action with previous one.

Record of conversation and action (1)

Child 2 [101]:	"(the submarine) folded its legs so that it kept going sideways"
[102]:	{points out LEG-FOLD block}
Child 1 [103]:	"See, isn't this opposite?"
[104]:	/{leans body towards the blocks, then points out LEG-FOLD and ROTATE block}
Child 2 [105]:	"I got it."
Child 1 [106]:	"First, we should fold the legs, and then 90 degrees|
Child 2 [107]:	"No, we should make it (program) this way."
[108]:	/{tries to set the parameter of the GO-FORWARD block}
[109]:	/{Its elbow prevents child 1 from attempting to reach the block}
Child 1 [110]:	"No, first we should fold the legs and then rotate 90 degrees, shouldn't we?"
[111]:	{leans body, making voice rough.}
[112]:	/{points out the ROTATE block}
Child 3 [113]:	"I think so."
Child 1 [114]:	"But this doesn't turn 90 degrees, so the legs don't come out."
[115]:	{tries to switch the LEG-FOLD and ROTATE}
Child 2 [116]:	"No, this should be .(not clear)."
Child 1 [117]:	"I guarantee."
[118]:	/{switches the LEG-FOLD and RO TATE}
[119]:	{sits down.}(after Child 2 and 3 completed the program)
Child 2 [120]:	"This (block) is attached here. That's why it didn't work."{still standing}
Child 3 [121]:	"there, there, let's try it."
[122]:	{press the execution switch}
Child 2 [123]:	{sits down.}

(The program was run. The submarine didn't reach the goal and the run ended)

Child 1 [124]:	{stands up}
[125]:	"This"
[126]:	/{points out a block}
Child 2 [127]:	"Shouldn't this be 45 degree opposite direction?"
[128]:	/{points out the block.}
Child 1 [129]:	"Oh, I understand".
Child 2 [130]:	{stands up}
Child 1 [131]:	{changes the parameter of the ROTATE block to 45 degrees to leftward.}
Child 2 [132]:	{sits down.}
Child 1 [133]:	{sits down.}
Child 3 [134]:	{presses the execution switch}

4.2.2. The control of collaboration by body movement and positioning

Working around the physical blocks induces children to turn their bodies toward the blocks and point them out. Through these movements, as previously stated, the direction of their attention is displayed to the other participants as apparent physical actions, thus each calls the others' attention. In [104], child 1 pointed out the LEG-FOLD block and ROTATE block. This pointing-out showed the direction of her attention to the other group members, and induced the other participants' attention to the same thing. By this pointing-out, the direction of each participant's eye lines were focused upon the same point, then the discussion over these blocks was begun. Also, in [104], child 1 leaned her body toward the blocks. Just as with the pointing-out, this action of leaning her body also can be considered as showing the direction of the attention of child 1 and to draw the other's attention there. Setting-body has the same function as pointing-out, however, being different from the action of pointing out a certain block, the range of the intention becomes slight wider. Boldly stated, the transactional space (Kendon 1990) would be set by setting-body, furthermore, the focus of the discussion would be set by pointing-out.

Also, through this record, it can be seen that the start and close of the discussion are achieved by their bodies movement. While running the program, child 1 and child 2 were watching the screen sitting down [119], [123]. However, when the run ended, they stood up [124], [130]. When standing up, the children's bodies were set toward the blocks. This made individual transactional spaces overlap on the blocks to form the F-formation (Kendon 1990). In other words, standing up and placing their bodies in position surrounding the command blocks makes them enter the space for group work. Conversely, when children sit down, their bodies are off the block, therefore this changing in the configuration dissolves the F-formation. Sitting while the program is running shows that their attention toward the blocks are released at that point, and they are in another phase of collaboration, such as looking at the screen together.

In [117]-[119], after presenting her own idea, child 1 was getting out from the shared transactional space by sitting down[119]. Against this, child 2 said, still standing up, "This is attached here. That's why it didn't work" [120]. It could be interpreted that, here, child 2 is trying to keep the shared work space by continuing her body set toward the block, then trying to continue the discussion. Child 2 sat down after child 3 had said, "there, there, let's try it" [121], and then had pressed the start switch [122]. After pressing the start switch, the program can not be changed. With this, the discussion is forced to end, then child 2 finally removed her body-set from the blocks.

In [131]-[134], you can see the completion of discussion generated by all children smoothly. After child 1 finished operating the blocks [131], child 2 first sat down [132]. As previously stated, sitting down could be interpreted as getting out of the space of group work, so it could be considered, through this action, that child 2 has no intention to make objections against the decision of child 1. After that, child 1 sat, too. It seems that she saw child 2 sitting down and realized that no new argument would occur. The two of them sitting at the same time indicates their intention: to not manipulate the blocks anymore, to child 3. Therefore, child 3 could press the start switch without asking anyone [134]. Here, the control of the collaborative work is achieved by mutual monitoring of body movements.

Control of collaboration by body movement and positioning is made possible through the tangibility of AlgoBlock which necessarily requires users to manipulate the program language surrounding the blocks physically, and it naturally draws body movement while manipulating the blocks. By using AlgoBlock, body movement and its positioning become usable as resources for the control of collaborative works. Here, the authors do not mention eye lines, however, AlgoBlock which is used by facing each other within the shared space, of course, can make it possible for children to use eye line as a tool for interaction. Summing up, AlgoBlock allows learners to utilize these familiar resource for interaction control, and through this, it enables active interaction among learners which is a crucial foundation for supporting community of learners.

4.2.3. AlgoBlock as an open tool

In [108], it can be said that child 2 operated the blocks by following her own idea. At first, the idea should be conceived as a result of her inner process and belonged to her. However, as soon as she tried to manipulate AlgoBlock, the idea was displayed to all of the participants through her body movement [108] which is necessarily generated by operating AlgoBlock and through visual change of the physical blocks as a result of her operation. Therefore, child 1 could instantly disagree [110], and then show her own idea as an alternative plan [110]-[115]. The child 1's idea was externalized to the other children for the same reason, then this induces the next response [113], [116]. In such a way, by using a tool which has actual substance, children can monitor the work the other participants are doing, what they are thinking and what their work situation is. They then can use each other's ideas as material for discussion. It can be said that AlgoBlock functions as an open tool which facilitates interaction among learners.

Furthermore, the following fragment suggests that openness of AlgoBlock improves ability of the group as a whole.

Record of conversation and action (2)

(The submarine is moving on the screen. Children are looking into CRT monitor while remaining seated)

Child 2 [200]:	"Ah, you don't have to use it there."
[201]:	{stands up pointing at the screen.}
Child 2 [202]:	{stands up and points out GO-FORWARD block which is tracing} (Each command block has a tracing lamp on its surface which indicates a block that is executed "now" by its blinking)
Child 3 [203]:	{Stands up}
Child 2 [204]:	"No, this won't be needed" {looks at GO-FORWARD block which child 1 pointed out, then points out ROTATE block located right after the forward block in the program}

This record shows that children recognized a programming error through the movement of the submarine, then pointed it out. In a glance, child 2 seems to resolve this problem alone. However it should have been impossible for child 2 to instantly point out the unnecessary ROTATE block among the row of blocks which was built longer at that time because when child 2 stood up, she was watching the screen, not programming [201]. In spite of it, child 2 pointed out the unnecessary block very promptly. It should be because she made use of the movement of child 1. At the same time that child 2 stood up, child 1 stood up pointing out GO-FORWARD block which is being traced. Through this movement, child 2 could promptly pick up the "doubtful" part in among the long programming and find the unnecessary block within the part. This immediate finding of the unnecessary block can be considered to be performed by the group collaboration between child 1 and child 2, and it is hard to say that it was due to individual's ability. By openness of AlgoBlock which allows each child to monitor each other's actions, the performance of the whole group, i.e., the community of learners, is improved.

4.3. Social designing of AlgoBlock: Conversation between communities

In this experimental setting, the social framework connecting the activities of using the AlgoBlock to the activities of the external world was not intended. Because of this, the activities of the children were closed in a special setting. In the experiment, it could be observed that children were forming and managing the temporary community with the purpose of working together by using the AlgoBlock. However, there would be no further development there. How to design a social situation that makes linkage between students' activities in the classroom and practices of the real world should be considered in a further study.

In regard to this, there was a very suggestive incident during the experiment. It was the questioning by an instructor to the children. During the experiment, the instructor asked the children twice "Is everything going according to your plan?" This instructor is one of the developers of AlgoBlock and has the ability to program; that is, he is one of the members of the community of programming. This question could be considered as being based upon the value of the programming community which admires thinking logical and solving problem under a plan. Regardless of whether the questioning was intentional or unintentional, its meaning for the children is the same. Actually, the question was ignored by the children both times, however, these questions had the potential of connecting the children's activities to the practice of the community of programming. It is because questions constrain persons who are questioned to respond to them. With these questions, children are forced to reconsider their method of solving problems which was adopted naturally through their practice, thus they are opened toward the change. The change is not necessarily considered to be happening only on the children's side. Children's responses, such as "Why is the plan needed?" also have a potential to force the instructor to reconsider the clear value of the programmer. Of course, these changes can not be expected to be inevitably occurring, though setting up a field for the dialogue between learners and the members of a community of practice can be a way to connect the children's activities to the outer social world.

5. Conclusion

The authors have presented AlgoBlock as an example of an educational tool to support forming and maintaining the community of learners, and then have shown the result in an evaluation experiment. It became clear that the essential feature of AlgoBlock was very effective in facilitating the interaction among learners. That should be a foundation for supporting activities in a community of learners. However, it is also clear that social designing of the tool is also required to make children's community function as an interface to programming community. Based upon these points, we are going to seek a design of the learning environment which will allow interactions within the community of learners to progress into the external world.

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Teaching Computer Science Students How to Work Together

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Abstract

As the number of jobs in which shared rather than individual work continues to grow, we are being forced to re-examine the waywe teach students to work. This paper suggests that in today's workplace, computer science students must be adept at both technical as well as cooperative skills. Towards this end, we developed a computer supported cooperative problem solving environment designed to teach undergraduate computer science majors how to elicit software requirements. We believe that requirements elicitation and cooperative skills are highly interrelated and, as such, can be taught more effectively through the use of a computer-supported cooperative environment. The environment encourages cooperative work, and yet provides instructors with the ability to monitor both individual and group performance. From our study, we found that students who used the computer-supported cooperative environment to elicit requirements performed better than those students who did the same task face-to-face.

1. Introduction

The primary goal of this research is to teach student programmers how to work together via a computer-supported cooperative problem solving environment. It was designed to achieve this goal by enhancing students' cooperative skills within the specific domain of requirements elicitation. The specific task addressed by this research is one in which student programmers located in different geographical sites develop requirements for a large software project. Thus, cooperative problem solving in this context refers to the shared, systematic behaviors displayed by two or more programmers as they develop a requirements document. In order for the students to communicate in this environment, a computer is used to assist the group in the performance of the task. As such, this particular computer-supported environment allows for synchronous communication between students who are separated by geographical distances (i.e., same time, different places).

The underlying model for this system states that effective cooperative problem solving is dependent on effective group competencies (Barge Hirokawa, 1989). An effective group competency is defined as a specific skill that helps a group complete a task (in this case, requirements elicitation) more effectively. Group competencies include, but are not necessarily limited to, establishing operating procedures, analyzing problems, selecting criteria for good solutions, generating alternative solutions, and evaluating solutions (Hirokawa Scheerhorn, 1986). We selected this particular model, as opposed to other models of computer-supported cooperative work (Aiken Carlisle, 1992; Dewan Riedl, 1993; Dykstra Carsik, 1991; Malone, Crowston, 1994; Moran Anderson, 1990; unamaker, Dennis, Vogel George, 1991; Winograd, 1986), because it provides a link between group interaction and problem solving *effectiveness*. Such a model is necessary given that our goal is to improve cooperative problem solving. Thus, it is proposed that cooperative problem solving is not only a matter of willingness, attitude, or direction; it is a skill that can be taught, assisted, and enhanced. Furthermore, we believe that effective group problem solving skills are instructable, if the particular skills involved can be articulated and practiced under circumstances that require their use.

In order to test these theories, we built and evaluated a special interface to support Computer-Supported Cooperative Training (CSCT). The system serves as a training environment where students learn to engage in technical, cooperative tasks such as working together on large programming projects. In addition to supporting network capabilities, the system has a series of shared windows or tools that represent and are linked to each of the above competencies for successful group problem solving.

After building the interface, we tested whether there were noticeable differences between "successful" and "unsuccessful" groups and related this to the use of the interface. Specifically, we asked: Can successful problem-solving groups be distinguished from less successful problem-solving groups on the basis of which shared tools are used in the problem-solving interaction and how often these tools are used? We found that the better groups showed more activities using tools that help generate and evaluate alternative solutions, more frequent use of tools that tested current knowledge, and more systematic use of all shared tools for problem solving (Swigger, Brazile DePew, 1993).

Results of these case studies were then used to make the shared tools more active. That is, we gave the system the ability to explain how each shared tool can be used to enhance a particular group problem solving skill. Thus, the system contains knowledge about a group competency as embodied in the different shared tools and knowledge about how to improve that competencies. When groups fail to display appropriate group behaviors through the use of one or more of the shared tools, the system intervenes and suggests alternative actions.

The next section explains the rationale for selecting the specific domain of requirements elicitation and provides a general overview of the cooperative problem solving interface. The following two sections describe the procedures used to build and enhance the training portion of our system. The last section concludes with a brief discussion and summary of the research.

2. System Overview

2.1. Collaboration and Requirements Elicitation

The context for our computer-supported cooperative interface is programmers engaged in eliciting requirements from users. The reason we selected this particular learning task was; a) it is a particularly difficult skill to teach, and b) it requires students to work together. Wexelblat (1987), for example, defines the software elicitation phase as "one of refinement through conversation" (p. 6) and argues that the problem space must be explored and shared between the user and analyst. By engaging in the group dynamics between programmer and user and programmer and programmer, the software developer learns to translate ambiguous, missing, or conflicting specifications into something resembling a fully developed program (Boland, 1978; Sommervile, 1992). As research notes, it is difficult to teach software elicitation at the introductory level, largely because so much of the student's energies are focused on learning the mechanics of programming and not on mastering the communication skills necessary for group work (Leite, 1987). There is also the problem of trying to teach and monitor collaboration within an introductory programming course and, at the same time, cover specific content. Thus, it would be helpful if someone could develop an environment that would allow students to master collaborative skills and, more importantly, exercise those skills within the context of a computer science task such as requirements elicitation. Through such a system, students could learn how collaboration supports the programming task.

2.2. Description of System

Having been convinced that requirements elicitation was an appropriate context for teaching collaboration, we then built a special interface to support this task. The CSCT environment is a highly interactive program, allowing student programmers to pose questions and conduct exchanges within the computer environment, testing and enriching their knowledge of group skills by manipulating various shared windows. The physical components of the current system include 486-based workstations running Windows and connected to a Local Area Network (LAN). The CSCT environment is provided by three program modules, a graphical user interface, LAN communications support, and a database management system. Group problem solving is accomplished by displaying information concurrently to all members of the task group. Each workstation logs the message content, time, date, etc., in a database that can be accessed for analysis at a later time. All users can react to the actions of others (i.e., text or graphics) immediately through shared displays. The interface permits a logical dialogue to occur by providing participants with the ability to access any of the shared displays (i.e., tools) at any time during the conversation. All behaviors are stored in a database which is extremely helpful when analyzing the conversational quality of the messages at a later time.

As previously stated, effective cooperative problem solving skills were delineated using a model of group competency as developed by (Hirokawa Scheerhorn, 1986; Hirokawa, 1983). The specific examples of "good" cooperative skills that were selected are: analyzing problems, using correct operating procedures, stating criteria, generating alternatives, and evaluating the solutions.

These behaviors were then encoded into the system via a series of shared tools or windows that represent each of the ommunication competencies. Thus, there is an shared tool that aids in problem orientation; another that helps in the establishment of criteria; a third that aids in the establishment of correct operating procedures; a fourth that helps solution generation and evaluation. The global cooperative tools can be accessed by participants at any time during the interaction. In addition there are several private tools that facilitate and enhance the shared tools. A more detail description of these tools now follows.

2.2.1 Collaborative Tools

A user, begins by selecting one of the available shared tools (i.e., Procedural Activity, Problem Definition, Criteria Establishment, or Solution Activity).

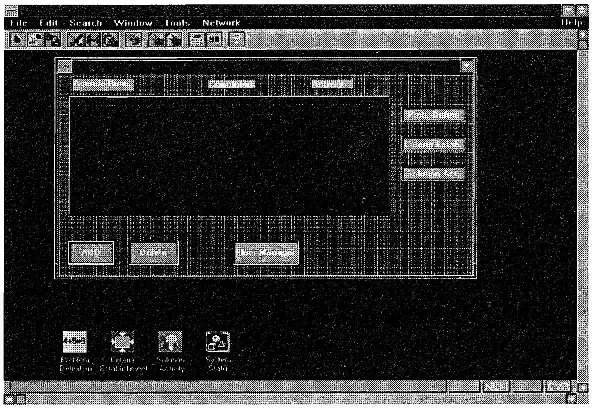

Figure 1. Procedural Activity Tool.

The *Procedural Activity Tool* is designed to help the group establish correct operating procedures (Fig. 1) and set an agenda. Voting and floor management are available that permit the group to structure and organize the discussion. Floor management styles include; a) choose a chairperson who manages the order of discussion (chairperson), b) allow the person in control to select the next speaker (sequential), c) submit a request in a simple linear, sequential, queuing order according to first-come, first-serve (competitive). The two voting options are majority rule and unanimous decision.

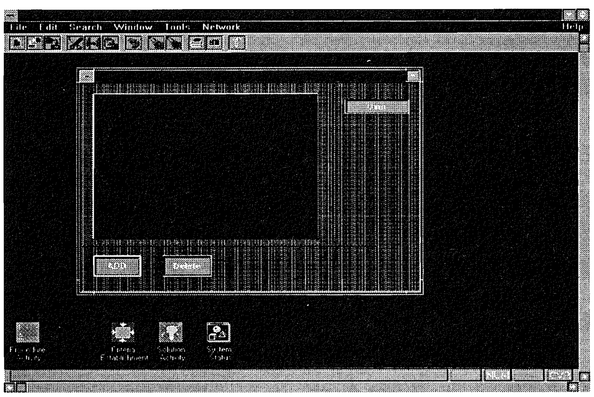

Figure 2. Problem Definition Tool.

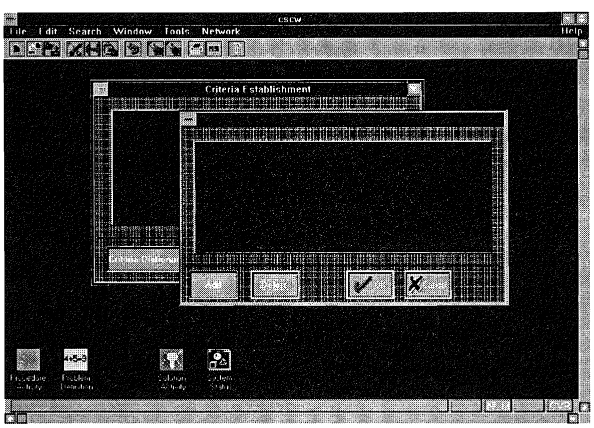

Figure 3. Criteria Establishment Tool.

The *Problem Definition Definition Tool* is used to analyze the group problem/task (Fig. 2). Group members enter their ideas via this tool and are able to indicate the extent or seriousness of the problem. Participants enter criteria for their requirements either directly into the *Criteria Establishment Tool* or by selecting one of the pre-defined criterion listed in the Criteria Dictionary subtool (Fig. 3). They must also assign a priority value to each criterion.

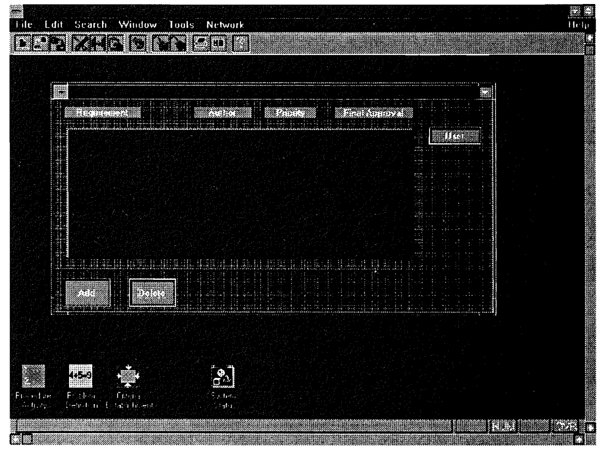

Figure 4. Solution Activity Tool.

Participants enter the actual requirements for the software specification problem through the *Solution Activity Tool* (Fig. 4). Participants specify a particular priority value with the requirement. Once all the requirements have been entered, a voting tool allows members to approve the various requirements.

After developing the different shared tools, we created a list of specific performance indicators that measure the various group competencies as defined by the shared tools. These performance indicators are lists of actions identified with the use of the shared tools and are intended to capture differential performance in this environment. For example, the performance indicators for the "Generation of Alternatives" competency include; the number of times the tool was used, the number of different modifications made while using the tool, the number of different members interacting with this tool, etc. The performance indicators are recorded in a group history file that is stored for each team.

3. Determining Optimal Behaviors for Teaching

Our first research task was to determine whether we could distinguish among different performers in this environment. More specifically, we wanted to be able to recognize the difference between effective and ineffective behavior so that we could remediate those groups who were performing poorly. We, therefore, asked the question: In terms of the specific performance indicators, what are the characteristics of those groups who are more successful in this particular environment?

This question was answered by examining the data from a series of computer problem solving sessions which recorded the performance of student programmers using the software. Forty-five computer science majors enrolled in an undergraduate software engineering course at the University of North Texas were assigned the task of writing a requirements specification document for developing a database for a ski resort. The subjects were randomly assigned to fifteen, three-member teams. One of the members of the group was assigned the role of the user, while the other two members were asked to be programmers. Each member of the team was escorted to a separate room where he/she was asked to communicate with the other team members using only the computer-supported cooperative training environment.

For the requirements elicitation task, group effectiveness was determined as the number of relevant requirements specified. These estimates were derived by asking three "expert" software engineering teachers to perform the exact same requirements elicitation task and then comparing the experts' lists to the subjects' list. After performing the task, the experts came together and developed a single list of approved requirements. A comparison between our experts' requirements and each of the group's requirements was then made, and a ratio of relevant requirements was computed for each group. Thus, a given group's problem solving effectiveness rating was based on a requirements score --- the higher the score, the more effective the group was assumed to be; the lower the score, the lesseffective the group was assumed to be.

Table 1. Correlations between shared tools and group effectiveness scores.

Communication Competency	Corr.(r)
Problem Orientation	.59 *
Establishment of Criteria	.06
Generation of Alternatives	.48 *
Solution Evaluation	.49 *
Establishing Operating Procedures	-.37

*p<.01

We then examined the activity level for the group competencies as characterized by the use of the shared tools for the groups. We first collapsed the performance indicator data for each group into a single index for each of the five competencies. The correlations of these five indicators with our effectiveness scores can be seen in Table 1. From this data, it is apparent that the performance indicators relating to problem orientation, generation of alternatives, and evaluation of solutions were the most highly correlated with successful cooperation. In addition, spending too much time managing the shared Procedural Orientation Tool seemed to have a slightly negative effect on subsequent cooperation. This information was then used to create the "teaching" portion of the interface.

4. Training Students to Collaborate

As previously mentioned, the CSCT environment has the instructional goal of teaching group problem solving skills. The system accomplishes this goal by constantly monitoring a group's use of the shared tools, comparing the group's activities to a model of good and poor performance, and then coaching team members to use the shared tools more effectively. The system keeps a detailed history list of how each of the shared tools was used. The system diagnoses solution quality by comparing the group's actions to a list of effective behaviors as specified in the previous section. Any suboptimal behaviors are collected into lists of potential problem areas and passed on to a coach for possible remediation.

For example, the model sequence of "good" behaviors in the requirements elicitation task involves: exploring the world informally and developing the problem for investigation (i.e., using the Problem Orientation tool); establishing the group's procedures by deciding how the interaction will take place, how it will reach consensus, and how it will manage the exchange (i.e., using the Procedural tool); determining the criteria of the requirements and its various constraints (i.e., using the Criteria tool); clarifying requirements, reorganizing the information, and determining if the requirements confirm or negate the user's idea of the problem (i.e., using the Solution Activity tool). We paid particular attention to those group behaviors deemed "most" predictive of problem solving effectiveness.

Using the above model and the list of performance indicators, we encoded tests, called "critics," that are used to determine the group's systematicity in using various shared tools (i.e., group competencies). A critic can be considered a program (or method) stored with the shared tool that tests the sequences of a group's actions. In addition, each shared tool contains tests that indicate where the group members might go astray. For instance, the critic for testing the group competency of "Generating Alternatives" checks whether the shared tool was invoked after the group set criteria and procedures, and whether there was a sufficient number of members who generated alternatives, an adequate number of items that were generated, and a sufficient number of items modified.

All competencies failing to reach a predetermined level of success or criterion performance become candidates for possible assistance. In the event that there are several ineffective behaviors, the system uses a conflict resolution strategy to make a decision as to which one needs addressing first.

The main question underlying this part of our work was whether fostering the use of specific collaborative skills would facilitate the learning of specific domain knowledge: in this case, requirements elicitation. This was tested by the interaction between testing occasion (i.e., requirements scores) and the instructional treatment (i.e., groups interacting with the full CSCT environment, groups who used a face-to-face technique, and groups using the CSCT environment without the critics). We again asked students enrolled in our undergraduate software engineering course to engage in a requirements elicitation project. Fifty-four subjects were randomly divided into sixteen, three-member groups. One-third of the groups were asked to perform their requirements elicitation task using face-to-face methods, one-third were asked to use the interface without the critics, and one-third the groups interacted with the full CSCT environment.

The criteria used to evaluate the quality of the group solutions for all groups was again the number of requirements as compared to our experts requirements. After completing the experiment, the data were analyzed to determine whether there were any differences among the three groups. A group means for the three groups are presented in Table 2. This interaction was significant when an ANOVA was computed on these data ($F = 5.66$; $p < .001$).

Table 2. Comparison of Effetiveness Scores.

Group	Mean Score
Computer-Supported with Critics	69.8
Computer-Supported without Critics	61.4
Face-To-Face	47.3

Subsequent analyses were also conducted on planned comparisons between the different treatment groups. The first comparison between groups using the computer-supported interface with and without critics and the face-to-face groups was significant ($p < .001$). In addition, the comparison between the Computer-Supported groups using the critics versus those without was also significant ($p < .05$). Thus, the performances of all groups using the computer-supported environment exceeded the performance of the face-to-face groups, and the computer-supported groups who used the interface with the critics outperformed the groups who used the interface without the critics.

5. Conclusion

In this research we assumed a situation for which there was a definite need for computer assistance: a system that would teach undergraduate computer science majors how to become more effective cooperative problem solvers while engaged in the task of requirements elicitation. We then built and evaluated just such a computer-based assistant:

- We developed a prototype based on a group competency model that allowed us to gather evidence on how groups use a computer to solve problems together.
- We developed shared tools representing group competencies designed to model effective problem solving strategies.
- We then used this information to augment the shared tools with knowledge about how and when to use the tools to improve task performance.

In our computer-supported cooperative environment, groups had the opportunity to engage in an active, exchange of information. Overall, the system worked as intended. First, it showed that meaningful relationships exist between the group behaviors as exemplified through shared tools and computer-supported cooperative problem-solving effectiveness. For example, we found that the more effective groups tended to use the tools differently than those groups who were less effective. These findings seem to confirm previous studies that the more effort spent in understanding the problem, generating ideas, and evaluating solutions the more likely the group will derive a correct solution (McBurney Hance, 1939). From these data, we were able to build critics that could facilitate computer-supported cooperative training, as evidenced in the second part of our study where effectiveness scores for the CSCT groups using the critics were higher than the face-to-face groups and the CSCT groups without critics.

Results from this study are now being used to modify the system further. We intend to run our experiments on a much larger sample to determine whether our initial results can be more fully substantiated. Experimental work on the modified system also includes an examination of the relationship between group effectiveness and the use of shared tools during different phases of the interaction.

Teaching cooperative skills, as characterized by special shared tools, has been the focus of this particular work. We believe that the current study shows that it is possible to improve requirements elicitation skills through tutoring on the cooperative problem solving skills. Thus, our goal is to use these results for developing broad-based systems that can be used in courses throughout the computer science curriculum. It is our observation that the need for cooperative skills occurs frequently in this technological society. Yet rarely do we teach people how to develop cooperative skills, nor do we provide proper tools for them to communicate in this mode. As such, this research should provide insight and software tools for teaching students how to use a computer to work together and solve problems.

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Supporting Collaborative Guided Inquiry in a Learning Environment for Biology

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Abstract

We describe a learning environment for high school biology called BGuILE that engages students in scientific investigations in which they can explore interesting problems in evolution and ecology. The environment supports productive inquiry by two interrelated means. First, the system structures students' investigations, encouraging them to compare competing hypotheses, articulate predictions, and record interpretations according to specific task models of biological inquiry. Second, the system provides a context for collaboration in which the biological task model is used to drive the content of students' discussions.

Keywords — microworlds, simulation, tools for inquiry learning.

1. Science Learning through Inquiry

Science education reformers argue that students should be active learners, directing their inquiry to construct and evaluate explanations, building upon their prior conceptions [1, 2]. Fostering scientific inquiry requires more support than providing opportunities for students to pose their own questions and tools for investigating them. Students differ widely in their success in learning from their own experimentation, depending on their prior domain knowledge and their use of more effective hypothesis generation, experimentation, and data organization skills [3]. There is little evidence that experience with inquiry alone improves these heuristics. Like other types of problem solving, inquiry draws upon strategies that are often implicit in expert explanations or even absent from instruction.

In this paper, we describe a computer-based learning environment for high school biology that teaches science by involving students in scientific investigations. We describe two essential aspects of support that enable more productive inquiry. The first is the collaborative context, in which students work together, serving as learning resources for each other, to pose questions, plan investigations, gather and interpret observations, and construct models. The second is the system's specific structuring of investigations through an on-line journal and an explicit strategic model for biological investigations. In the following sections, we describe this inquiry support and the role that collaboration plays in this learning activity.

2. Overview of BGuILE

BGuILE, *Biology Guided Inquiry Learning Environment*, teaches science as a process in which students construct, evaluate, iteratively refine, and then communicate explanations. BGuILE presents puzzling natural phenomena and offers a set of analytical tools and inquiry prompts to enable students to investigate and explain them. BGuILE's complex problem contexts enable students to consider a number of competing but plausible hypotheses. We structure students' investigation of these complex scenarios as a guided collaboration. The collective generation of potential hypotheses, discussion of merits and failings of competing predictions, and evaluation of evidence can be more effective than a single student attempting to perform and coordinate these processes.

BGuILE provides a range of support for the inquiry process. First, BGuILE supports general investigation strategies with its tightly-integrated inquiry journal. The journal is an on-line system that helps students articulate and reflect on their investigations as they construct questions, pose hypotheses, gather observations, and record interpretations. More specific support is also required to help students focus on relevant questions and interpretations. The system helps students structure their investigations according to a *task model* of biological investigations by focusing students on the types of observations and interpretations biologists use to explain phenomena. For instance, a behavioral ecologist is primarily concerned with making comparisons between organisms and finding costs and benefits associated with a behavior. An understanding of this task model can help students take a more planful approach in their investigations.

BGuILE provides two types of investigative activities in evolution and ecology. *Focused investigations* present a scenario in which students study a curious outcome and are asked to explain it. *Simulations* allow students to explore questions by conducting controlled experiments in a simulated ecosystem. Students use analytical tools to investigate their hypotheses by measuring characteristics of an organism, its behavior, or the environment. The first prototype for BGuILE's focused investigation and simulation scenarios will be evaluated in a classroom setting in July 1995.

The collaborative context is an important aspect of making inquiry more productive. Students can internalize the process of inquiry as one of proposing conjectures and evaluating alternatives more easily after these processes have been practiced in a group context, perhaps with different individuals proposing alternatives and providing supporting evidence or competing explanations. Our central aim is to focus students on the process of planning and conducting a coherent investigation to build an explanatory model. For this reason, we focus on computer support for face-to-face interactions as students work to understand the phenomena — observing behavior, selecting situations to test their ideas, and making sense of the results — rather than in supporting communication between students. Thus, the computer environment provides a context for shared work [4] — groups of students collaborate to construct coherent arguments, based on well-structured investigation, which they can then communicate to their audience for discussion. Fostering productive inquiry requires more than placing students in a collaborative setting. We use task models of biological investigation to drive the content of students' dialogue. Thus, the inquiry support in BGuILE that explicitly prompts students to compare and interpret data, looking for selection pressures or costs and benefits of behaviors, provides clear goals for the group's negotiations.

3. Inquiry Support

Central to BGuILE is the notion of guided inquiry. One crucial form of guidance in the system is support for students' development of effective strategies for scientific investigation. It is unlikely that such general skills can be taught directly, therefore our approach is to exemplify more general investigative strategies within the domains of evolutionary biology and ecology represented in the system. Thus, the inquiry support in BGuILE is designed to be both at the level of general scientific investigation strategies and domain-specific strategies and heuristics.

The on-line inquiry journal is designed to foster students' development of domain-independent scientific investigation strategies. The journal presents each group of students with a shared, structured space in which to explicate their reasoning during inquiry, providing opportunities for articulation of and reflection on strategies usually implicit [5, 6]. Students actively construct paths through their investigations as they carry them out, using a pre-defined vocabulary of inquiry elements and links reflective of scientific reasoning (e.g., stating hypotheses, making predictions, interpreting data). These various elements can be linked together in constrained ways to construct a structured graph of the investigation. Group discussions centered around such concrete representations of the chain of investigation are critical to students coming to understand the nature of scientific inquiry and adopting effective strategies to pursue inquiry within scientific domains.

The structure provided by the journal supports complementary aspects of collaboration: encouraging students to discuss and reach consensus on specific strategies, while allowing for multiple points of view to be expressed as multiple lines of inquiry. The journal provides students with a framework within which to articulate their reasoning steps and negotiate consensus on what those steps should be. Thus, to enter a new hypothesis, a group of students collaborating on the investigation of some question will have to agree both on what it means for some statement to be a hypothesis, and whether or not the particular hypothesis is reasonable for the current investigation. This negotiation requires group members to reflect upon and articulate their reasoning for the group. It is not desirable, however, to proceed solely through consensus [7, 8]. A second advantage of the journal is that it supports the tracking of multiple lines of inquiry, allowing expression of different opinions and perhaps preventing a single student from dominating the group.

The investigation graph itself is an object available for reflection and discussion. The journal acts as a kind of conversational prop [9] which can guide students' debate about the course of their investigation. Students may be able to discern more and less effective strategies of investigation in patterns of linking between elements in their journal. For example, students can readily see if they have a number of hypotheses which have yet to be tested, or if they have experimented across a breadth of hypotheses, but not explored any single hypothesis in depth. This structure of the journal not only supports students' investigations into particular domain questions, but on seeing science as a process of argumentation rather than a simple search for facts.

While the journal provides a global view of the progress of an investigation, local guidance integrated with particular steps in the scenarios encourages students to act more planfully during their investigations. Students are prompted to provide rationales for specific observations and analyses in terms of how they can further the current investigation. Following the performance of some test, students are prompted to interpret their results, again in terms of their overall investigations. Through these prompts, students are encouraged to reflect upon how a particular test can further their investigative goals, and to consider how data bear upon their emerging explanations. These local rationales and interpretations are then recorded in the journal, along with students' results, and students are encouraged to link these elements into their existing investigation graphs. Thus, students are encouraged to relate their local observations to their overarching investigations.

These local prompts also reflect specific task models of biological inquiry. For example, when examining the amount of rainfall within a specified time span on a Galapagos island, students are prompted to consider how that will help them identify a selection pressure on the local bird population. Upon seeing the rainfall data, students are encouraged to consider whether that in itself is sufficient to act as a pressure or whether some other environmental factor may be at work. Thus, besides encouraging students to relate their individual steps to their investigations, these prompts help reinforce investigation strategies useful in the domain.

4. Biological Inquiry in BGuILE

The inquiry journal provides one layer of inquiry support, an additional layer is embedded in the design of the investigation activities. To make student-directed investigations more productive, the system must make otherwise invisible features observable, and should focus students on the types of analyses and interpretation strategies used in the domain (such as looking for selection pressures, variation in a trait, cost-benefit analyses of a behavior, etc.). The following sections describe two types of investigative activities in evolutionary biology and behavioral ecology.

4.1. Focused investigations

The focused investigations present students with a series of scenarios, based on data from actual biological investigations, in which students see a curious outcome and are asked to investigate and explain it. The overall design of the scenarios, in which students can examine potential causes looking for possible explanations, focuses students on the type of cause-effect reasoning necessary to build causal models.

One sample scenario states that the number of finches on a Galapagos island has significantly dropped in the last year, and asks students to explain why some of the finches are surviving while others are dying. In reality, finches were starving due to a severe drought. Normally, the birds' diet consists of small, soft seeds, but these did not survive the drought. A more resilient plant that yields large, hard, thorny seeds was still available. Finches with a slightly deeper beak were better able to eat the larger seeds and survive the drought [10].

The accepted explanation for this scenario is not intuitive, and the causal relationships are not immediately obvious. Students might raise and explore a number of conjectures, before considering the relationship of weather, food availability, and structural differences among birds. The environment provides a suite of analytical tools that enable students to gather information, and synthesis tools that reify the investigation strategies used by evolutionary biologists. The analytical tools enable students to take measurements on the surviving birds, look at what they eat, observe behavior in the natural habitat, and examine characteristics of the environment. The synthesis tools consist of a compare tool and a relate tool. The compare tool allows students to recognize trends and correlations by comparing any type of data collected with the analytical tools. The relate tool encourages students to identify and articulate relationships, such as structural-behavioral relationships, among the trends they observe.

The tools are designed to scaffold the type of reasoning required in explaining evolutionary phenomena, such as recognizing variations, changes over time, and relating behavioral and structural information. For example, students can compare finches' beak size. The display of this data shows not only the mean value, but represents the distribution of values for the chosen population. Students may note that finch 5 and finch 17 lie at opposite ends of the distribution. Next, they might go to the field notes (which simulate notes taken by scientists making observations in the field). Looking at observations of finch 5 and finch 17, they see that finch 5 twists and twists the seed but is unable to crack it, but finch 17 grabs the whole seed in its beak and cracks it open. Students can also use the analytical tools to collect information from a representative set of time periods. Information from one time period can be compared with information from another time period using the compare tool.

The design of the tools and environment were informed by a number of pilot studies using a paper-based mock up of the environment. We expect that using tools that reflect a task model of evolutionary biology will help students to form causal models.

4.2. Experimentation with simulations

The simulation we are building, *Animal Landlord*, will serve as an environment in which students form causal stories about animal behavior by articulating predictions about various features affecting an animal and testing these within a simulated world. We want students to make behavioral arguments, from observation to explanation, about complicated behavioral events. The simulation is designed to investigate questions of the form: 1) If a creature displays behavior *X*, what would be the effects, and 2) What must be true of a creature in order for it to behave in manner *X*.

The simulation might depict a lion attack on a herd of zebras: students would see the lions foraging, perceiving the zebras, assuming a stalking position, and finally attacking as a group. Within this presentation are a number of interesting factors for analysis, including [11]: What is the relationship between the size of the lion pride and this success rate? How does the behavior of the zebras, once they realize that they are under siege, affect this capture rate? Are there benefits to group hunting, or could a single lion fare just as well if not better? Students can manipulate aspects of the simulated ecosystem and creatures to see how these and other factors contribute to an explanation of the causality involved in the lions' hunt.

Making sense of interactions and focusing on intermediate steps of the hunt (as opposed to final outcomes) would be difficult for students [3, 6]. We intend to scaffold learning by providing explicit focus on causally relevant features and support for experimentation through the system's task model for investigations and the integration of the inquiry journal.

First, we deliver models of the world that simplify the number of features requiring student attention, focusing on a pedagogically relevant subset. Second, we want to reduce the opacity associated with quantitative models by building a qualitative architecture emphasizing behaviors. Third, we want to provide multiple representations of world phenomena to accentuate salient properties. For example, the system generates a timeline of actions seen during the lion hunt, providing a static representation of the world dynamics, focusing attention on the animals' state changes, and providing explanatory and background information about the simulated behaviors.

The goal-directed task of exploring the lion hunt is meant to provide a stronger context for inquiry than more open-ended animal behavior simulations [12, 13]. Our first goal is to have students explore the world with specific questions in mind, such as "How big should a lion hunting group be to catch the most zebra?" The system focuses students on the domain-specific observational methods that behavioral ecologists might use to answer such a question. For instance, students might try to discover the optimal group size by looking for variations among different population sizes to discover their chances of success. Students must decide what form the investigation should take, the requisite observations, and the ultimate data interpretation.

5. Conclusions

We have described a computer environment for supporting guided collaborative inquiry. Inquiry support in BGuILE consists of both a general model of scientific inquiry as well as specific task models for biology. The structure and prompts provided by the system serve not only to engender effective biological investigations, but also to foster productive, focused discussions among students. This guided collaboration reflects in the social context the various aspects of the inquiry process that must be internalized, such as comparing competing alternatives, mustering evidence pro and con, and looking for selection pressures. Finally, the nature of the task in which the group must come to consensus to review evidence and revise models focuses students on seeing science as a process of argumentation rather than as a search for facts.

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Supporting Collaborative Learning during Information Searching

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Abstract

We consider the role of collaborative learning during information searching. We report on observations of situated collaboration in a physical library, which informed the development of our system, Ariadne. This was intended both to investigate and support the learning of search skills. An iterative development and testing methodology was applied. The system has a mechanism for recording an interaction history of the search process. A visualisation of this process makes it easier for users to reflect, share and comment upon their understanding with others.

Keywords — Information searching, collaborative browsing, iterative development, search visualisation.

1. Introduction

The use of library resources is stereotyped as a solitary activity with, until recently, little mention in the library science and information retrieval literature of the social aspects of information systems. However, end-users do engage in significant collaboration; both with co-searchers, library staff, professional colleagues and other interested parties [8, 13]. The trend to increased remote access of information stores is changing the nature of social interactions in libraries and this will inevitably affect the collaboration that occurs [21].

Our approach is pragmatic rather than theory-driven as the role of collaborative learning in information searching is relatively unexplored. Similarly, the system should be regarded as much as a tool for investigating the phenomenon as it is a tool for actually supporting users. We report on observations of situated collaboration in physical libraries and the subsequent iterative development and testing of the system, Ariadne, intended to help investigate collaborative learning of search skills. We describe mechanisms both to preserve existing collaboration and to enable new forms in digital libraries.

2. Collaboration in Information Searching

We first consider the problems that end-users have in using information systems, and then look at the role of collaborative learning in addressing these issues.

2.1. Information Searching

Increasing numbers of students are using online resources including OPACs (Online Public-Access Catalogues) and bibliographic databases as part of their studies. Information searching is also becoming one of the transferable skills expected of all graduates. However, the numerous problems end-users have in effectively using online databases are well documented (e.g. [3, 29]). Common problems include: retrieving zero hits [7], retrieving hundreds of hits [11], frequent errors [2], little strategy variation [10] and locating few of the relevant records [9].

Such reports have led to a paradigm shift in the field of information science from a system-centred view of information systems to a user-centred (or 'sense-making') approach [6, 14]. This constructivist view to searching recognises that users seek information from a variety of sources to satisfy their information needs. These needs are often initially vague and evolve during the search process so that *browsing* is a more accurate description of users' behaviour than *searching* [1]. The term browsing emphasises the indeterminate, situated and serendipitous aspects of searching [4, 15, 17] which contrast sharply with the single-query/single-answer model of traditional information retrieval [18].

Browsing is not limited to physical books or their electronic representations. That people are a valuable source of information is acknowledged in the importance placed on the user-intermediary reference interview (e.g. [5, 12, 23]). The centrality of this interaction for librarians appears to have led to an under-appreciation of the collaboration *between* end-users and how this can result in the collaborative learning of information skills.

2.2. Collaborative Learning

Information searching is an interesting context to investigate collaborative learning because it involves two processes: learning about the domain in question (say, Psychology) and learning about how to locate information. The two processes are inextricably linked – information skills can't be effectively taught in an abstract manner. In other words, (as librarians themselves have noted) it is difficult to learn about searching for information without actually searching for some *real* information.

There is a notable trend, certainly in the UK University sector, for increased use of collaborative learning for two disparate reasons. The first is the belief in its educational advantages [22] including greater student enjoyment and motivation as well as greater relevance to real-world modes of working. The second is the perceived cost savings compared to conventional individual-oriented education [28].

What is remarkable about the learning of information skills is that some students *spontaneously* choose to collaborate. That is, unlike other forms of collaborative learning where we as educators have to set up structures to ensure collaboration occurs, in the searching context it happens independently through student-initiated actions.

Part of this spontaneous collaboration is a by-product of organised collaboration. For example, students working on a group Psychology assignment are likely to work together in the information searching stage of the activity – mutually learning information searching skills. However, other instances of collaborative learning that we have observed occur independently of formally organised groups.

Inevitably, there are problems. Peers may not be able to answer all questions, some help may be confusing or simply wrong, and groups may reach impasses where they need help from outside their peer group. Therefore, any attempt to encourage collaborative learning also needs to support the occasions when it breaks down. While database browsing, the group may consult different kinds of people: other more expert peers, library staff and their subject tutor(s). All these outsiders will find the giving of help far easier if they have a context; a record of what the group has currently achieved and where problems arose [5]. As well as indicating the true source of the problem, something that novices may find particularly difficult to articulate (it is of course hard to discuss in the abstract something you know you don't understand), an activity trace also gives an expert clues about the degree of sophistication of the questioners, allowing her to phrase her explanation at the appropriate level of detail.

3. Observations of Information Searching

Given that it may seem counter-intuitive that library usage does indeed contain significant aspects of collaboration, we would encourage readers of this paper to spend a short time observing users in their local physical library.

Our own informal observations have shown notable work-related collaborations (excluding social chat) of roughly two every ten minutes around a bay of 12 OPAC terminals [25] and similar amounts round a group of PCs providing access to bibliographic CD-ROMs. This figure gives an indication of an order of magnitude of significance; other studies, both at Lancaster and elsewhere, are clearly required.

Several kinds of collaborative interactions between users have been observed:

- A group of students (2-4) work around a single terminal, discussing their ideas and planning their next actions. The interaction involves frequent pointing at the terminal screen. They are involved in a group task, either one set as such by their lecturer or one where they have chosen to collaborate on searching the literature before working on their individual assignments.

- A group working on adjacent terminals, discussing what they are doing, comparing results, sometimes seemingly competing to find the information. Much leaning over terminals occurs and they may occasionally all cluster around one terminal.

- Individuals working at adjacent terminals occasionally leaning over and asking their neighbour for help. These questions could be asked of a member of the library staff, but it is much more convenient (and perhaps less embarrassing) to ask a neighbour rather than to stand in a queue at the enquiries desk. In addition, the helper can see the context of the questioner's problem, something that is lost (with existing technology) if the questioner leaves her terminal.

- Individuals working at separate terminals monitoring the activity of others. There is a substantial degree of awareness while working in the library. Much of this is social (e.g. noticing friends walking past), but some appears to be an informal monitoring of the activity of others. Occasionally, this leads to a query of the form "How did you do that?". These interactions were rarer than the other kinds and occurred, unsurprisingly, most often between colleagues.

- Patterns of work intersect at a communal resource such as a printer or a photocopier. For example, a student printing search results found an uncollected printout and inquired whose it was – when the owner was identified he proceeded to use the results to discuss the CD-ROM system.

This degree of collaboration is notable not merely because it appears to be ignored in the library and information science literature, but also because the context it occurs in might be expected to reduce the likelihood for collaboration. Libraries are perceived as quiet places where talking is frowned upon and where people go to study alone. Furthermore, bibliographic systems are designed only to support users working alone. Despite these social and technological constraints, collaborations still do occur [8, 13].

Nevertheless there are features that encourage collaboration. Library staff do endeavour to make libraries more welcoming [16]. In the case of Lancaster University Library, the layout promotes informal social interaction by placing communal services (help desks, photocopying, etc.) around a large public space. The OPAC terminals we observed were in this busy area.

This physicality is worthy of note because as libraries become increasingly networked and virtual, the necessity of physically working in the library will diminish [21]. A side effect will be that the existing opportunities for spontaneous co-located synchronous collaboration will likewise diminish [13, 16].

The move to digital libraries offers great potential for *increased* collaborative learning – collaborations with users remotely located but electronically linked using the same resources. However we need to ensure that our systems not only provide mechanisms to allow new forms of collaboration, but also cater for (or compensate for the loss of) the existing forms. There is a danger that this will not happen for two reasons:

- As the collaborative nature of library usage is hardly recognised in the research literature, OPAC developers are unlikely to take it into account.

- Historically, the developers of databases have attempted to make the impact of other users as near invisible as possible, thus eliminating the possibilities of collaboration [19].

4. The Ariadne System

Based on our studies of existing, spontaneous collaboration we have developed, and are refining, a system (Ariadne) to support the collaborative learning of database browsing skills [24].

4.1. Aims for the System

Ariadne is intended to serve two purposes:

- To allow us to observe, record, analyse and experiment with the collaborative learning process. Studies of the use of Ariadne such as those outlined below will provide us with more detailed information about the nature of the process we wish to support. This information will be complementary to that obtained from situated observations of collaboration in libraries.

- To provide a system which enhances the opportunities and effectiveness of the collaborative learning that already occurs. We also want to include facilities that will allow collaborations to persist as people increasingly search information remotely.

As a result of these twin aims, the development of Ariadne employs an evolutionary approach, with continual testing of the system by users. As noted, collaboration often occurs despite the features of existing systems rather than because of them. In particular, although the more sophisticated bibliographic database systems provide various options for recording (and possibly sharing) the *product* of a search activity (the hits obtained), none that we are aware of provide any mechanism for sharing the *process* (how the hits were obtained). The latter is just as important in the former in facilitating collaborative learning as the following scenarios illustrate:

- A user wishes to explain how to employ a browsing strategy to a colleague. If they happen to be in the same place a demonstration *may* suffice. However, having a record of the process is clearly useful, as a focus for clarifying discussion of the process and allowing the learner to take the record away with her. In asynchronous collaborations a record of the process is even more important.

- A user wishing to ask for help, can approach a colleague with a record of her process and say "I did *this*, what am I doing wrong?"

- A user wishes to share with a colleague not just what they have found but *how* she found it. The colleague can then continue by considering which strategies have not yet been employed.

- Examples of best practice can be circulated in the learning community. Even though the topics of the actual searches may not be of relevance to the co-learners, the strategies that they embody can be, particularly if they have annotations. Just as useful can be the circulation of poor searches, coupled with annotations of what is wrong with them.

Our observations of database usage by novices and the work of others [1, 20] leads us to believe that one of the causes of the poor performance of novices is that they lack an overview of the browsing process. As a result they lack any systematic strategy for investigating the available information and for using interim results for refining the search process. Therefore, we believe it is important to provide a visualisation that can serve as an overview of a complete interaction history.

4.2. Data Capture

The system captures the users' input (key strokes) and the database/library system's output (text-based screen dumps). These are then combined to form a series of *command–output* pairs, each pair being represented as an item in the Ariadne browser. This means data capture is done transparently: so that users can work as if they were interacting directly with their chosen database. It is only in the subsequent playback phase that the new form of working becomes available.

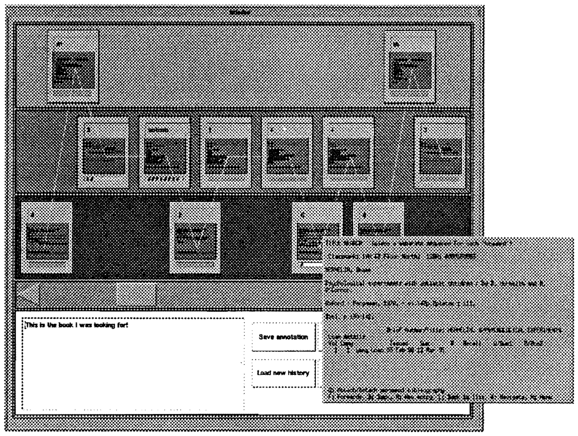

Figure 1. The Ariadne system interface (the open card has the database menu command '6')

The simplicity of the approach ensures that it can be used for *any* text based interface for *any* library for which remote access via Telnet is possible. This separation between capture and display is necessary because of the lack of separation between the user interface of a database and the database functionality itself. Therefore, the separation we provide allows the graphical Ariadne interface to work both with data captured in this way and (potentially) through other methods (e.g. by the Z39.50 protocol).

4.3. Playback

The system interprets the command–output pairs and creates a card representation for each one. Each card consists of the users' command, a thumbnail (miniaturised version) of the screendump and an annotation indicator (Figure 1). The thumbnail can be expanded by clicking on it to open a window showing the full sized view of the screenshot. The aim of the thumbnail is to act as a reminder of the underlying text. For example, it is easy to distinguish between the thumbnails of a menu screen and a database record. The interface consists of two areas, one depicting the users' browse path and one that supports annotation of the cards, separated by the scrollbar.

The browse area is sub-divided into three levels to provide a two-dimensional representation of the information searching process. The aim is to give an impression of 'diving' into a database by composing queries and going down to actual data entries. A session consists of numerous 'dives' into detail, interspersed by 'higher level' activities of composing and combining searches, selecting display options etc. For example, screen shots of top level menus are located in the top level, whereas individual book references are positioned in the lowest level. The browser employs a set of rules that define the positional semantics of the cards. Each set of rules is fixed and specific to the type of database/library system used in the search. The rules provide a first approximation to the impression of 'data diving'. Users can override the rules by moving any card up or down through the levels. The cards are placed in a 'trail'. A 'chalkline' is drawn over the trail to emphasise the chronological ordering of the search (Figure 1).

Selecting the annotation indicator box at the bottom of a card loads the annotation associated with that card (if any) into the annotation editor. Cards with annotations attached are distinguished by having a differently coloured annotation box which also displays an indication of the size of the annotation.

A user may collapse, or *fold*, parts of the search allowing information to be temporarily hidden. A new card is created denoting the presence of a *folded region* (Figure 2). Folds may be nested, annotated and expanded. The large number of cards that result from a lengthy search make it desirable to group together and hide a sequence of cards in order to focus on the larger picture. For example, a substantial part of a search may have involved looking in turn at a collection of, say, 23 hits. These can be folded away in order to get a better view of the other actions that took place during the search. The folds and annotations can also be saved.

Currently Ariadne can be used to record and play back interactions with the OPAC system used by Lancaster's Library and BIDS, a national online bibliographic database. In addition to revising and expanding Ariadne's functionality, we intend extending the coverage of the systems that it can support.

5. Testing of Ariadne

We believe that formative evaluation of the system should be as authentic as possible [26]. Therefore, testing has involved the use of volunteers who bring a problem that they already have to solve, rather than our imposing a standardised problem upon them. The latter approach has many problems, not least that the implicit assumptions in the design of the system are likely to also be manifested in the design of the activity to be performed in the evaluation, thus reducing the chances of detecting those assumptions, and of revealing the requirements of actual users.

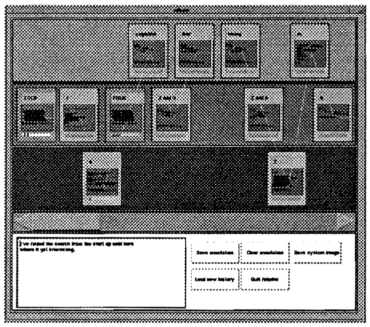

Figure 2. A search visualisation in Ariadne showing folding and annotation.

Given the incremental development of Ariadne, the results of the sequence of testing are necessarily both preliminary and anecdotal. Nevertheless we believe that the results obtained are of importance in informing subsequent development of the system and in contributing to our understanding of the nature of the behaviour we wish to support [27].

5.1. Collaborative Use of Ariadne

Five groups of four undergraduate Psychology students chose to use the system to help them with their group assignment. They had to agree a general theme in Cognitive Psychology and then each student had to pick a more precise topic to study in detail from the primary literature. They were each to produce an individual report which would be collected together and, with an initial linking chapter, would form their coursework document. The students used Ariadne (largely with BIDS) at the beginning of the task, both to decide on their collective theme and on their individual subtopics. This activity revealed one of the key characteristics of browsing; how the goals evolve over time. The process of analysing retrieved hits from a search led the groups to redefine what it was that they wished to investigate. Some groups chose to return to continue working in later sessions, as individuals, subgroups and full groups. Most students were unfamiliar with bibliographic databases but confident in using the basic options of Lancaster's OPAC.

An initial concern was that the concept of visualising a search process might require a certain degree of understanding of the nature of bibliographic database use. For competent users it is fairly clear that a record of their actions would allow them to reflect on what they have done, share and discuss it with colleagues and consider alternatives and improvements. What was less clear was whether the system would be of use to relative novices.

5.2. Comprehension of the Search Visualisation

Users were able to understand the 2D visualisation of the search. They were happy to scroll over their earlier searches, opening up screens to examine in detail the what they had done and use that in group discussions of what they should do next, and how they should do it.

This is encouraging, given that :

- None of them had ever experienced any visualisation of search process before.
- Some were very unfamiliar with computer use, particularly graphical workstations.
- Many had only a very rudimentary understanding of the nature of information browsing in databases, and the strategies and tactics that can be applied.

5.3. Observations on Ariadne Usage

The history representation became a focus for discussion. This has been noted for other CSCW and CSCL systems [27]. For those groups who chose to return for subsequent sessions, the ability to rapidly review the search they performed a week or more ago proved to be a useful orientation activity, particularly where the group members had not convened in other circumstances since the last session.

Users were keen to get printouts of information they had found. Consequently an option to print the contents of a card was added. Numerous other minor changes to the interface were made in the light of the iterative testing and development. Although seemingly minor, interface issues such as the positioning and wording of menu options can have a enormous effect on usability for novices. A consequence of this is that the folding and annotation facilities have received less testing as they have evolved rapidly. Most of their use has so far been by the experimenter when acting as a domain expert, as noted below.

Groups of novice users inevitably hit problems which they could not solve collaboratively. In such cases, when asked, the experimenter intervened and acted as an information intermediary (such as a subject librarian). Ariadne's visualisation proved particularly useful for explaining and summarising to the group what they had done and to initiate discussion of what they might try next.

Many mistakes were made in searching. These can be caused by substantial misconceptions about the nature of bibliographic databases [29], but also by simple typing errors. The latter are of concern because of occasions when a group attempted a perfectly sound strategy, but due to a minor error (a typing or syntactic mistake), the action failed to yield anything and so the strategy was abandoned. The users may not be aware of the error and, we observed in some cases, refused to believe that they had made it until confronted with the evidence of the history on the screen.

Searches can be performed but not investigated. That is, the users undertake a search and get a reasonable number of hits, but fail to look at these hits, not even listing their titles. Instead they go on and do another search, and in the cases we note here, never go back to examine the results. This can be due to the presence of multiple search goals, so that completing one leads to attempting the next before the results of the first are examined. Another observed cause was that undertaking one search inspired an idea for another tactic, and the users got carried away with trying out this technique before examining the results of their earlier trial. This behaviour has been noted both for individuals and for groups. We believe the situation may be more acute for groups, where a number of participants have competing suggestions for the next search tactic to try. The ability to subsequently view their actions using Ariadne proved useful to some groups in revealing this problem, and in inspiring group members to suggest subsequent search activities. Other groups were not aware of gaps in their searching until the experimenter intervened.

6. Future Work

So far, all the testing of Ariadne has been synchronous and co-located. We have also undertaken small scale studies of other modes of cooperative working [24] which indicated problems with the usefulness of synchronous remote collaboration. Therefore, we are developing Ariadne to support asynchronous, remote collaboration. One aspect of this will be the sending of annotated searches using electronic mail. In order to investigate another approach, we have already implemented an option to convert the record of a search into a sequence of World Wide Web (WWW) pages. Examples can be found at:
http://www.comp.lancs.ac.uk/computing/research/aai-aied/information/ariadne/

6.1. New Functionality

The latest version of Ariadne also has a collaborative window to support asynchronous communication (Figure 3). The thumbnails of the cards on the main browsing window may be selected and dragged over to the text editor of the collaborative window and dropped into it. The toggle buttons (whose details are obtained from the user's own resource file) denote users and groups who are to receive the message. A user may communicate with a number of other users and groups by selecting an appropriate combination of toggle buttons. Two modes of communication are possible:

- The contents of the text editor may be sent. This utilises a normal email service which allows users to extract the text based information held within the Ariadne browser.

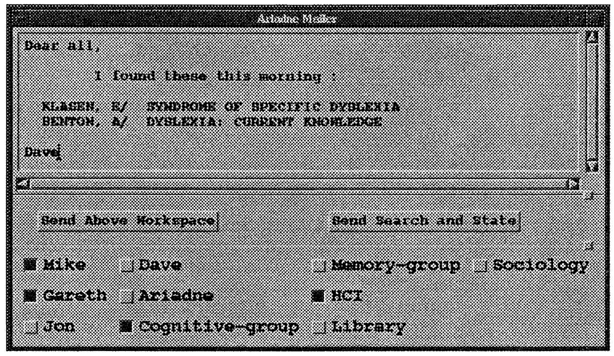

Figure 3. The Ariadne collaborative window.

- The user can send her current search in its existing state. This can then be visualised, further annotated and returned or forwarded to others.

We believe that if we are to facilitate the widest possible degree of collaboration we need to allow for a range of technologies and platforms. Although closely cooperating group members may all be using the same technology, they may wish to draw on the assistance of an outsider who does not have the same systems available. Hence the group may use Ariadne to cooperate between themselves, but have to resort to the WWW histories or conventional email for working with others. Collaborative systems should be designed to support a graceful degradation of functionality to permit a wider degree of participation.

7. Conclusion

We have described how the computer supported collaborative aspects of learning information searching skills have been relatively ignored. Students already use libraries as locations to undertake collaborative learning. We believe it to be important to provide users with mechanisms that allow them to share the process of their searching activities as well as its product, and also for the systems to facilitate an awareness of others. Our system, Ariadne, allows us to investigate how to support existing collaboration and to address the challenges and opportunities that the transition to digital libraries affords.

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Cyber Bosnia: Computer-Mediated Communications in a War Zone

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Abstract

Computer-mediated communication is being used by peace workers and aid agencies as part of their work in the Balkan war zone. The ZaMir Transnational Network (ZTN), a member of the Association for Progressive Communications (APC), has established a communi-cations infrastructure that crosses boundries and ethnic barriers. This appplication of the new information technology consists of refugee mail services, coordination of humanitarian relief efforts, media subsitution and the creation of a cross-national anti-war coalition.

Keywords — *CMC, social use of IT, social movements.*

1. No Electronic Escape

> *"All those stories how nice and how good it was in ex-Yugoslavia are fairy-tales of the past. A virtual reality, as the virtual reality that Bosnia was such a peaceful country, it may was, but it isn't anymore. Wars have left their scares and war is NOT broken houses, it is broken MINDS. Living in a "war" zone is living in a virtual reality, a reality based on rumors and worries for the future...."*[1] (Wam Kat, peace worker & communications activist)

The Internet is not just fun and games for youngsters and yuppies, or restricted to academic exchanges, or moving the shopping mall to our home computer. The new information technology can be part of socially meaningful action. The work of communications activists in the Balkan war zone is such use. For these peace workers "Cyber Bosnia" is not an electronic escape but a way to relieve some of the suffering of the war, hopefully to make a contribution to ending it.

2. ZaMir Networking

In late 1991, the pan-Yugoslavian amatuer Adrianet was crumbling. It was becoming increasingly difficult to use the telephone systems between the component parts of former Yugoslavia. And the FIDO technology used by amatuer and citizen networks relies on dial-up modem connections over telephone lines. In order to guarantee stable connectivity between anti-war and humanitarian groups, communications activists began probing possibilities of linking to systems with a political profile such as the PeaceNews BBS in Belgrad, already used by local groups for communication and information exchange. Some help was obtained from peace and humanitarian groups in Sweden, the Netherlands, Switzerland, Austria and Germany.[2]

The Antiwar Campaign in Zagreb and the Center for Antiwar Action in Belgrade decided to set up their own BBS network. In July 1992 the first systems were installed. This was the beginning of the ZaMir ("For Peace") network, linked from the start to the Association for Progressive Communications and the rest of the Internet.[3] When it became impossible or extremely difficult to maintain direct communication links between the various parts of former Yugoslavia, then relayed links were set up. When it was not possible to call from Zagreb to Belgrade, then calls were made to a "node" (station) which could connect to both. Connec-

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[1]Wam Kat, Topic 2036 "Yugoslavs as virtual reality", Response 3 of 4 in <yugo.antiwar> 3:01 pm Dec 17, 1994 (at ZAMIR-ZG.comlink.apc.org)

[2]Joel Sax in <apc.forum>, "Networks in Yugoland", Dec.23, 1992

[3]Eric Bachman, "Communications Aid for the Peace Movements in the former republics of Yugoslavia", Report, September 1991- May 1993", Balkan Gopher, (8) ZAMIRnet...nr 1. Updated in correspondence with Eric Bachman, May 6, 1995.

tions have gone through GreenNet in London, LINK-ATU in Vienna, and later BIONIC in Bielefeld, Germany. Interviewed in a Reuters news release, Rena Tangens, a co-operator of the Bielefeld link, put it this way:

> *"It sounds crazy to send a message from Serbia to Bielefeld in order to contact someone in Croatia," she concedes.*
>
> *But with neighbors once less than an hour's drive apart now divided by battle lines and severed telephone cables, it is for many the only way to communicate. Mail is no alternative. In Bosnia the postal service has broken down, between Serbia and Croatia it is extinct.*
>
> *What we have created is the most reliable communicaton link with and within the former Yugoslavia," Tangens says.*[4]

By mid 1993, the Zagreb-Belgrade link was being used by about 500 users, with 35 different groups online. At this time, each of the BBSes sent and/or received about 500 to 200 kilobytes a day, which is between 250 to 1000 pages of text. Messages were both private e-mail and public postings. Usage expanded and by mid 1995, there were about 1500 users on the system.

The ZaMir network expanded, adopting the name ZaMir Transnational Net (ZTN). By early 1995 additional stations had joined: in Ljublana, Sarajevo, Pristina and Tuzla. In November 1994, ZTN became a full member of the APC., dedicated to peace, the environment, human rights and sustainable development.[5]

3. Content of the ZTN

The ZTN, rooted as it is in the peace movement, is dedicated to maintaining open channels of dialogue between the warring factions and across boundries. While it does not allow propagandizing or beligerant "shouting", the ZTN is dedicated to the "open flow" ideology. This flow takes several different forms within the ZTN and the other info-footpaths into Cyber Bosnia: e-mail, refugee mail services, conferencing, electronic publishing and archive services.

The ZTN helps coordinate humanitarian aid for some of the many refugees of the war. It has become an important means of communication for humanitarian organisations working in the war region and sister organisations in other countries. The ZTN facilitates the search for volunteers for reconstructing the damage of the war in all parts of former Yugoslavia. In order to facilitate e-mail exchanges, a database of groups and organizations is being compiled. Wam Kat, volunteer who came for one month to Croatia has ended up staying. He began to write a dairy so that his two young sons would later know what their father was doing. His "Zagreb Diary" is posted regularly in the public APC/ZTN conference called <yugo.antiwar>.This diary has been distributed widely electronically, reprinted, and royalties help finance the ZTN.[6]

4. Refugee Mail Services

Refugee work was given priority since it soon became evident that computer-mediated communications could both complement and speed up refugee support work of the kind carried on by agencies such as the Red Cross/Red Crescent.[7] Using connections organized in and around the APC, ZTN and the Internet in general, two refugee mail services collaborate to carry letters for refugees and others in and out of besieged cities in former Yugoslavia. These services are the Sarajevo Pony Express (SPE) and PISMA (Servis za Pisma). The former, with its clearing house at PeaceNet/IGC in San Francisco, is responsible for international traffic and PISMA for regional delivery. This service combines computer-mediated communications with fax linkages with to-the-door delivery by relief and peace workers.[8]

5. Conferencing as Communicative Interaction

In 1991, the Swedish Peace and Arbitration Society, Sweden's largest and the world's oldest existing peace organization, opened an online conference <yugo.antiwar>, which has become something of a communications hub in Cyber Bosnia. People from all around the world participate in this conference. Topics deal not only with the war and refugees but also with culture and exchanges such as classroom to classroom projects.[9]

At the request of aid workers, a special APC con-

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[4]Reuters, "Internet keeps Yugoslavia connected to global village", posted in <yugo.antiwar>, Topic 2108, Jan. 26, 1995.

[5]Eric Bachman, "ZANA-PR in Wonderland" in Balkan gopher at gopher.igc.apc.org, ZTN5:(reprint from KOHA magazine, Nov 94) Eric Bachman, "ZaMir Transnational Net" (11 Nov 1994), ZTN3:, updated 6 April 1995 in correspondence with Eric Bachman, May 6, 1995.

[6]Ibid.

[7]Wam Kat at ZaMIR-ZG, Nov. 29, 1992, reposted in <apc.forum> 362.2, Dec. 23, 1992.

[8]Eric Bachman, loc.cit..; Ed Agro, in "SPE/PISMA Refugee Mail Services: History and Operation" at Balkan gopher: gopher.igc.apc.org.

[9]Ibid.

ference for refugee work was started. <exyugo.refugee> The contents here deal with aid coordination, appeals and announcements, finding people. One effort deals with an international war resister's network for aiding war resisters to the present Balkan war. Another APC conference <reg.exyugoslavia> contains official documents, press releases from different governments, agencies and organisations. Besides APC conferences, the ZTN has its own set of conferences, mainly in the regional languages, for discussion and for helping people find each other.

The Geneva BBS of the International Council of Voluntary Agencies (ICVA) uses the ZTN for communications with its field workers.[10]

January 28, 1995 marked the 1000th day of the siege of Sarajevo. This tragic commemoration was protested against by peace groups in Serbia, Croatia, Bosnia and around the world. Peace and Sarajevo support groups in Belgrade, the capital of Serbia, protested the continuing siege of Sarajevo, even though they themselves had suffered from the international blockade of their country. These protest activities were coordinated online.[11]

These examples illustrate a salient feature of electronic conferencing: the subject content can be either local, global or both. Material can be structured by dedicating different conferences to different issue areas. ZTN and APC conferences are mostly moderated, to keep people to the content area. Some USENET conferences deal with the Balkans, such as <soc.culture.bosnia-herzgvna>. While not analyzed in this study, there is a growing concern among netters that these unmoderated electronic fora may become unrulely, vehicles for narrow-mindedness or worse. Drawing parallels to war-torn Bosnia, BIX editor George Bond is concerned that certain Internet trends may be contributing to the degeneration of CMC as a citizen's medium for rational discourse.[12]

6. Media Substitution

A major use of computer-mediated communication is for media substitution. CMC can also be used for distributing and retrieving information that simply cannot be spread or found elsewhere. Volunteers, concerned academics and organizations around the world often gather reports, articles and news, or produce original items, on certain subjects and then forward this material to interested users of e-mail. This metod of publishing and/or broadcasting is known as "maillist" (or listmail or listserv). A maillist is just what the name implies: material is sent out over the Internet as e-mail to a list of electronic subscribers, who automatically get the listserv publication(s) in their e-mailbox. The material sent out in this way is "moderated" (controlled) usually from a clearly identified source or sources. In some systems, the maillists are put in to conferences on a host computer. These "read only" conferences function then as maillists but with indexing, which allows a user to choose what he or she wants to "download", that is transfer to their own computer.

In the beginning of 1995 the "South Slavic Mailing Lists Directory" contained the following:

- Bosnet - a moderated, volunteer forum for redistribution of information;
- Croatian-News / Hrvatski-Vjesnik - a moderated, volunteer forum for redistribution of information;
- Cro-News / SCYU-Digest - a non-moderated distribution point (from the WELL) for news;
- CRO-VIEWS - a non-moderated Australian service and an academic level of discussion is encouraged.
- Kuharske Bukve - a weekly Slovene-language cook book;
- MAK-NEWS - two bi-lingual news services from the University of Buffalo on Macadonia;
- Novice MZT - News of Ministry of Science and Technology of the Republic of Slovenia;
- Oglasna Deska - bulletin board of usenet type conferences in Slovenia, multi-lingual;
- Pisma Bralcev - an edited (not moderated) mailing list which provides the possibility of publishing readers' opinions, questions, inquiries for help, answers etc., multi-lingual;
- RokPress - a moderated mailing list, intended primarily for news from Slovenia. mainly in Slovene;
- SAGE-net - a moderated group/forum run by student volunteers from the group Students Against GEnocide (SAGE)--Project Bosnia. Its goals are to initiate and coordinate activities among groups active on Bosnia, particularly those on university and college campuses.
- SII - unmoderated network for distribution of news and discussions about the current events in ex-Yu, centered around those involving or affecting Serbs;
- ST-L (Srpska terminologija/Serbian Terminology) - for discussing Serbian terminology ...
- Vreme - carries "Vreme News Digest" (selected articles from "Vreme" translated to English).
- YU-QWest Mejling Lista - unmoderated forum for exiles and emigrants from the territory of the for-

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[10] Eric Bachman, loc.cit.

[11] Topic 2106 "Belgrade Groups Protest 1000th day" in <yugo.antiwar>, 6:03 pm Jan 26, 1995 (at ZAMIR-BG.comlink.apc.org).

[12] *BYTE*, March, 1995.

mer republic of Yugoslavia.[13]

Seven of these maillists are based in the USA, the UK or Australia (albeit with much exile input); four are joint Slovene-North American projects; one (MAK-NEWS) appears to be a multinational effort, though with Anglo-Saxon predominance; one is purely Solvene and one purely Serbian, one seems to be Polish-American. The list servers of Cyber Bosnia thus appear to be an Anglo-Saxon affair. It would be most interesting to know how these rich information services are actually being used, both in the Balkan region and around the globe.

The ZTN distributes critical analyses of mainstream media, which have played, according to many, a key role in whipping up nationalism and war hysteria in the whole region. One such media watchdog publication is ARKzin, which publishes summaries electronically in <yugo.antiwar>. Another example of electronic publishing in Cyber Bosnia are exile magazines such as *Dialogue,* from Amsterdam.[14] The need for media substitution may sometimes tend to overshadow the communicative-coordination aspects of global, inter-organizational conferencing, as the two mix in a blend of information, analysis and action.[15]

A major interchange in Cyber Bosnia is the Balkan gopher at PeaceNet in San Francisco. This gopher collects and organizes information on current events in and around the Balkans. For example, it carries a documentation section on war crimes in the territory of former Yugoslavia, mainly bulletins of the Republic of Bosnia - Hercegovina State War Crimes Commission, in several languages. An archiving service has started at the University of Essex in the United Kingdom with the task of gathering and cataloging electronic material from and on the Balkans.

7. Actors and Spectators in Cyber Bosnia

A major tool for communication and interaction between people using computer-mediated systems like ZTN is conferencing. In an online conference system, an individual can post his or her views, publications and statements. These can then be read and commented upon by other users of the system. That this is a new electronic forum for public discourse and coordination of meaningful action is exemplified by the utopian usages of electronic conferencing on the ZTN and connected networks. This type of use of CMC strengthens civil society.

One of the most important parts of building up an anti-war movement is coordination between groups. This is for the obvious purpose of planning joint activities but also for the equally important psychological effect of knowing that one is not alone. In this respect, computer-mediated communication is a powerful tool. Besides its immediate humanitarian importance , this type of computer-mediated communication has shown itself to have other longterm effects. CMC helps maintain communities in exile through the creation and support for group identity, for internal and external communication and for effective political action. The experience of the ZTN in establishing and maintaining crisis communications in a war zone underscores that effective networking for social change has to be global in its perspective and organization.[16]

Acknowledgments

This article is part of a larger study on the utopian uses of computer-mediated communication, based on research and the author's first hand experiences in building up a "node" (NordNet) within the community of networks known as the APC -the Association for Progressive Communications. Financial support for the research has been received from the University of Stockholm and the Swedish Council for Planning and Coordination of Research (*Forskningsrådsnämnden, FRN*). Helpful comments and corrections on this paper have been provided by Eric Bachman at BIONIC and Ed Agro at PeaceNet's Balkan Gopher..

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13Topic 2092 "South-Slav Mailing Lists (Upd)", Mailing-Lists@KRPAN.ARNES.SI (South Slavic Mailing Lists Directory), from <igc:pnbalkans> in <yugo.antiwar> 9:00 pm Jan 14, 1995.

14Topic 215 "Introduction to DIALOGUE mizamir" in <yugo.antiwar> 2:01 pm Jan 29, 1995 (at antenna.nl).

15Cf Wam Kat's comment on this in <yugo.antiwar>, Topic 1773, Jul 24, 1994.

16Cf. Tiger Li, " Computer-Mediated Communications and the Chinese Students in the U.S.", in *Information Society*, 1990, vol 7: 125-137; Howard H. Frederick, "Computer Communications in Cross-Border Coalition-Building: North American NGO Networking Against NAFTA," in *Gazette* 50:217.241, 1992; Howard Frederick, "Computer Networks and the Emergence of Global Civil Society: The Case of the Association for Progressive Communications (APC)". in *Global Networks: Computers and International Communication*, ed. Linda M. Harasim , Cambridge Mass., MIT Press, 1993.

Appendix

Balkan gopher: gopher.igc.apc.org or www.igc.apc.org

Eric Bachman, coordinator, ZaMir Transnational Network: e.bachman@bionic.zer.de

Belgrade: support@ZAMIR-BG.ztn.apc.org
Ljublana: support@ZAMIR-LJ.ztn.apc.org
Sarajevo: support@ZAMIR-SA.ztn.apc.org
Tuzla: support@ZAMIR-TZ.ztn.apc.org
Zagreb: support@ZAMIR-ZG.ztn.apc.org
Pristina: support@ZANA-PR.ztn.apc.org

For information on the APC, contact (in the USA):
Institute for Global Communications
(EcoNet/PeaceNet/ConflictNet/LaborNet)
18 de Boom Street
San Francisco, CA 94 107, USA
e-mail: support@igc.apc.org.

Computer Support for Pupils Collaborating: A Case Study on Collisions

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Abstract

This study set out to investigate collaborative learning in pairs of students solving physics problems with a computer. It tested the hypothesis that peer facilitation effects are improved ifparticipants have conflicting models of the task. Subjects working inpairs were more likely to improve their post test scores and to succeed in the problem solving exercise thansubjects working totally alone or alone yet in the presence of others. Ourmain result, which is surprising, suggests that pairs with 'similar' pointsof view did best.

Keywords — Classroom discourse processes, collaboration andconceptual change, collaborative composition.

1. Introduction

This paper reports the results of a study focusing upon the effects of peercollaboration, peer presence and peer absence when subjects are engaged incomputer based physics problem solving activities. We wished to understandmore clearly what were the benefits of working with a partner, i.e. can they all be attributed tointeractional processes? The influential work of Doise and Mugny [1], has given particular impetus to the study of group composition and theirwork predicts that group-generated conflict stimulates the jointconstruction of a more advanced concept which is then individuallyinternalised. This study set out to investigate collaborative learning between pairs of students solving physics problemswith a computer. It tested the hypothesis that peer facilitation effectsare improved if participants have conflicting models of the task. Theresearch takes its direction from Piagetian theory which holds that conflict creates disequilibrium which canthen lead students to attempt the construction of new knowledge. If thetheory is correct, it should follow that peer collaboration should provesuperior to individual learning or situation.

Although there is a body of research focusing on the benefits of peerinteraction in the context of computer use (e.g. Howe et al [2], Light andBlaye [3] and O'Malley [4]), there is now a growing interest into theeffects of social facilitation in computer based learning. Studies with children have foundthat peer presence facilitates problem solving (Joiner et al [5]) and thatgender too has a mediating effect (Loveridge et al [6]).

In the light of this work we were interested in investigating threeissues:

1. Does socio-cognitive conflict maximise learning within pairs?
2. Do pairs perform better than individuals?
3. What effect does working alone, yet in the presence of others, have uponperformance?

The results from our study indicate that subjects interacting together as pairs do performsignificantly better than subjects working totally alone. However, pupilsworking simply in the presence of others also exhibit a superiorperformance to subjects left to struggle alone. The pupils working alone, yet in the presence of others adopted amore systematic investigation of the domain than subjects working totallyalone. This observation suggests that peer presence has a motivationaleffect while interaction within a pair served to draw attention to critical instances in the simulation whichcould aid further understanding in a domain of known conceptualdifficulty.

2. Method

2.1. Subjects

The pupils, involved in these studies comprised of a selection of fifteenyear olds (mean age = 15.1 years, sd = 0.67) from an 'all-ability' schoolin Hoddesdon, serving a mainly working-class catchment area. Pupils allstudied a double science G.C.S.E. course, which was taught in a modular fashion. The pupils who took part in the collaborative study were paired according to whether they had similaror different views about the motion of pucks sliding on ice after acollision, (data obtained from pre test questionnaire). These groups werebalanced in terms of ability level by the class teachers. We chose to study single sex dyads as this was thecurrent practice for teaching within the school. The subjects who workedalone were randomly assigned to the 'coactive' (i.e. used the computer inthe presence of others) or the 'single' (used the computer totally alone) condition. The numbers in each groupare shown in Table 1 below.

2.2 Procedure

The pupils were firstly pre tested with an extended version of thequestionnaire developed by Whitelock et al [7]. This included a predictiontask where subjects were asked to predict the subsequent motion of two icepucks after collision for the following three cases:

Case 1: Puck A is small and light; Puck B is largerand heavier.

Case 2: Puck A is large and heavy; Puck B is smaller and lighter.

Case 3: Puck A and Puck B are identical.

N.B. Puck A always hits a stationary Puck B.

The subjects were questioned about theirunderstanding of kinetic energy and momentum. Most of these laterquestions were taken from, or adapted from, the APU Science in schools: Age15 report, (Welford et al [8]).

Table 1. Numbers of pupils who worked in the'paired' or "single" condition when using the PuckLand program.

PUPIL GROUP	n
BOYS 'SIMILAR'	22
BOYS 'DIFFERENT'	18
BOYS 'COACTIVE"	12
BOYS 'SINGLE'	14
GIRLS 'SIMILAR'	22
GIRLS 'DIFFERENT'	16
GIRLS 'COACTIVE'	9
GIRLS 'SINGLE'	9

The pupils were taken (in pairs or as singles) to a sixth formteaching room where a Macintosh SE computer was set up on a table. In the'coactive' condition i.e. where subjects worked alone yet in the presenceof others, the sixth form teaching room contained seven Macintosh computers. and subjects could see each other'sscreens. Only the pairs were videotaped.

2.3 The Computer Simulation

The PuckLand simulation was written in Hypercard 2 for use with the AppleMacintosh computer. It used a direct manipulation approach, (Shneiderman[9]) which allowed students to investigate a series of collisions betweentwo ice pucks. It consisted of a pair of pinball-style flippers on either side of the screen with whichsubjects could flick pucks. The amount of force with which the flippershit the pucks could be varied, as could the mass of the pucks. The icepucks, ranging from 1 to 100 units of mass, could be dragged into position ready to be struck by theflippers. The initial velocity of the collision was controlled by directlymanipulating the angle of the flipper from 90 to 180 degrees in the vertical plane. When the "Go" button was activated the pucks moved towards each other on the screen and wereanimated with a speed proportional to that set by the initial angle ofimpact executed by the flipper.

After the pucks collided they moved away fromeach other with a speed which was calculated from the correct physics formalisms. This meant that theprinciples of conservation of momentum and kinetic energy were obeyed andagain the apparent screen velocities of the pucks was proportional to theircalculated values. At the bottom of the screen was a grid which provided numerical information about theamount of energy and momentum that the system had initially, and then,subsequent to being run, it showed what the effect of the collision was onthese two factors. Every experiment attempted by users of the simulation was automatically logged by thecomputer.

2.4 . Using the Simulation

All the subjects, whether they worked in pairs or alone, had access totheir paper and pencil task predictions about the motion of the ice pucksafter collision. They were asked to think about their predictions interms of what sorts of experiments they would like to try with the simulation. Subjects who worked in pairs wereasked to actually discuss their predictions with each other and to try and sort out any differences between them before running their experimentson a Mac SE. All subjects then had access to the computer simulation,where they had time to check out their predictions and to experiment withany other situations which interested them. The subjects working as individuals were also actively encouragedto predict their original predictions against the results given by thesimulation. (N.B. The length of session for each group was notconstrained).

Once the subjects felt they had learnt all they could by experimenting without help with thesimulation they were asked to solve three different problems, which wereposed in order of difficulty. These problems required the subjects not topredict the result of a collision but to state the original conditions for a given outcome. The problems were asfollows:

1. What initial conditions arė needed to send thep-ucks travelling away from each other at the same speed?

2. What initial conditions are needed to make one puck stop after impact?

3. What initial conditions are needed to make puck-sof unequal masses move away, after impact, at the same speed?

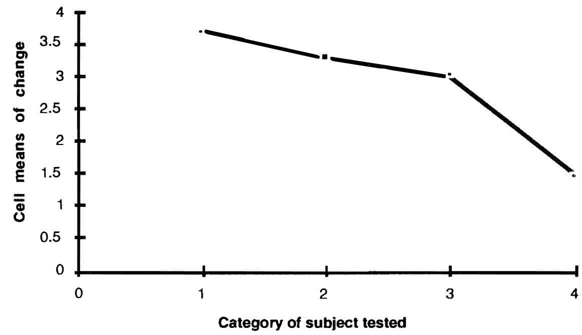
The purpose of the final phase of the experiment was to ascertain whatthe pupils had learnt and so they were asked to describe he most importantfactors that should be taken into account in order to perform thep-rediction task correctly. Since the pupils working alone could not discuss their results they completed awritten summary of their conclusions on their instruction sheet, where they had also recorded their answers to the problem solvingexercises. All subjects were post tested, with the same problems and underidentical conditions as used in the pretest, 3-4 days after they had usedPuckland.

3. Results

The key finding from this experiment is that, of all the groupstested, pairs do best in terms of post test gain. The plot of changescores versus group category (see Figure 1) illustrates that both thesimilar paired condition and the different paired condition perform better than subjects in the single condition. However,the coactives i.e. the pupils who worked alone yet in the presence of others did better than those in the single condition. A one way ANOVAperformed on the pre-post test change scores revealed no overall difference according to condition but apostoripairwise comparisons revealed a significant difference between the changescores of pupils working individually and those working in similar pairs(Fishers protected LSP $p<0.05$). Pupils working in similar pairs made a greater pre to post test improvementthan those working alone. There were no significant differences between'-girls similar' and 'boys similar' post - test scores but the 'similargirls' pretest ($t = 3.2$, $p=0.1$) was significantly lower than the others. The dialogues led us to suspect thatthe girls had less experiential knowledge of collisions than the boys andthis affected their predictions, (i.e. they did not play snooker, footballor even hockey and did not use analogies from any sporting experiences to make predictions). This findingis similar to that reported by (Johnson and Murphy [10]).

As well as looking simply at improvement on pre to post test scoresit was possible to investigate problem solving success when subjects wereusing the simulation alone and in pairs (See figure 2). The three problemswere given in order of difficulty and all the pupils in the paired condition were able to answer question1. This was not the case for 'boys coactive' and boys and girls working alone. In fact the single condition for problem1 is significantly different from that of the 'similar' , 'different' and'coactive' conditions (Fishers protected LSP $p<0.05$).

Figure 1. Graph to illustrate change scores versusgroup category.



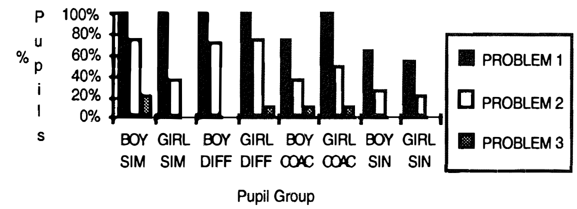
Key: 1 = 'similar', 2 ='different', 3 = 'coactive', 4 = 'single' .

For problem 2 and 3 there were no significantdifference across groups. In fact Problem 3 proved to be too difficultfor most of the subjects. This data supports the Piagetian hypothesis that working in pairs should besuperior to working alone. However we have also found that pupils workingin the presence of others have better scores than those working totally alone. Therefore further analysis of the number and range of experiments performed with Puckland wasundertaken to find reasons for these group differences.

The pupils in the single condition spentsignificantly less total time using PuckLand, (Fishers protected LSP $p<0.05$) than those in the 'similar, 'different' and 'coactive' conditions . Thereis no significant difference between the time spent by pairs in theexploratory phase but significant differences between the pairs andthe single condition and the pairs and the coactive conditions in this phase. The pairs, like the coactives,spent longer exploring the domain before they wanted to complete theproblem solving tasks. These results suggest that one of the factorscontributing to problem solving success with this simulation is allowing enough time to become familiar with thedomain before rushing into the problem solving.

One very interesting finding from the analysis is that the girlsbenefited more than the boys from the 'coactive' condition. Theypersevered longer with the experimental phase than the boys in the'coactive' condition. They were more conscious of what their peers were doing throughout the whole experiment, making use of theauditory clues provided by the simulation. For example when the sticks hit the puck there is a sound which is followed by a loudernoise when both pucks collide. They used this cue to assess how theirpeers were progressing and hence continued with the work while theyunderstood others were persevering with the task in hand.

Figure 2. Percentage of pupils who solved each ofthe Puckland problems.



Key: Sim = 'similar' partner, Diff ='different' partner, Coact = 'coactive' (working alone but in the presence ofothers), Sin = 'single'

To summarise: the pairs investigated all the scenarios where our previous work hasshown pupils experienced conceptual difficulty. The 'coactives' and'singles' did not exhibit an identical behaviour but unlike the pairs thecoactives experimented with limiting conditions cases. The lack of investigation of critical events by pupilsworking alone suggests that a partner can draw attention to unexpectedphenomena. This aspect was the missing ingredient from the 'coactive' and'single' conditions. It is suggested that working in pairs can encourage a "predict, observe and explain"modus operandi which in turn can facilitate subjects "seeing" theunexpected phenomena.

4. Conclusion

The results indicate that on this computer-based investigation subjectsworking in pairs were more likely to improve their post test scores and tosucceed in the problem solving exercise than subjects working alone. However there was no significant difference between the pairs. The Video analysis of the interaction between thepairs revealed more instances of conflict among the different pairs however,there were far fewer conflicts than expected, in fact only 28 in total with16 recorded among the different pairs. All subjects however, tried toresolve these conflicts but only one remained unresolved among the similar pairs and three were unresolved amongthe different pairs. Two separate strategies were employed to resolveconflict these were achieved by appealing to the computer for the correctanswer and secondly by talking the problem through by themselves. Resolution of conflict by the computer wasused more frequently by 'different' pairs and the other strategy of talkingthrough the problem was used more by the 'similar' pairs. This resultsuggests that co-operative construction of shared meaning maybe a more important consideration than conflictin successful collaboration (Barbeiri and Light [11]).

We found that subjects working in the 'coactive'or 'single' condition perform more experiments than the pairs. However, it was not the number but type of experiments investigated that was animportant factor in understanding the nature of collisions. Both the pairsand the singles spent more time exploring the domain before attempting theproblem solving exercises. Not only were the range of experiments different within the groups but moreimportantly the approach. It appeared that the pairs did better becausethey adopted a "predict, observe, explain" modus operandi which was notattempted by the pupils working as individuals in the 'coactive' or in the single condition. This observationsuggested that peer presence had a motivational effect and that anxiety waslowered when subjects worked in the presence of others. This appeared areasonable conclusion since two subjects in the single condition were so stressed they abandoned theexperiment less than half way through. The 'coactives' performed betterthan the singles and also felt they had learnt more as revealed by theircomments at the end of the experiment.

Similar' pairs did perform significantly better than pupils workingtotally alone and although they performed better than the 'coactives', there was a benefit not only from peer interaction but also from peerpresence. In our case peer presence prevented subjects from giving up, they felt more relaxed and persevered in aproductive fashion exhibiting less trial and error behaviour than thesingles. The magnitude of such peer presence effects is controversial. (e.g. Light et al [12], and Mevarech et al [13].

Our results suggested that a "predict, observe, explain" methodology(see e.g. Champagne et al [14], aids subject understanding of a domain. The adoption of this strategy has proved to be successful when used by bothHennessy et al [15] and Howe et al [2]. Although Howe's work has found that most benefits occur whenmembers of a pair have different views we have found that children canprogress without necessarily having reached a more advanced solution duringinteraction. An important finding from our study is that the performance gains by the 'coactive'group suggested that it was not just the interaction but the physicalpresence of others sharing the same task which lowered anxiety levels andincreased subject motivation although we did not collect measures of these, our results are based on observationsof subject behaviour. To conclude our main result is surprising and doesnot support one popular view of the benefits of collaboration. Oursubsidiary results cast light on the role of experiments in developing pupils conceptual understanding, modes ofcollaborative working and the design of interactive learningenvironments.

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An Historical Perspective on Instructional Design: Is it Time to Exchange Skinner's Teaching Machine for Dewey's Toolbox?

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Abstract

Student learning is not accidental: it is the direct result of what has been designed, intentionally or unintentionally, by teachers, schools, curriculum developers and communities. Behind teaching and learnng events are beliefs about learning which directly influence what students experience. This paper provides an historical perspective on current instructional design practices. While attendees at this conference may find it easy to discount the inadequacy of traditional theories of instruction, an understanding of the historical evolution of these theories and their pervasive influence on K-12 education is necessary if we want to support teaching reform efforts. Without an understanding of the evolution of current teaching practices, change efforts may be unsuccessful.

1. The Efficiency Movement

Prior to 1900, educational practice possessed little in terms of a theoretical framework, was certainly not considered scientific or subject to scientific study, but was a holistic enterprise in which teachers were expected to teach facts while also shaping character. Popular curricula included the *McGuffy Readers*, a collection of moral tales designed to build character in American students.

In the second half of the 19th century, European scholars theorized that it was possible to develop methods which would make the study of human behavior more scientific. The ideas of Wilhelm Wundt in Germany and Francis Galton in England heavily influenced the development of a new American School of Psychology and along with it the emerging field of educational psychology. Stanley Hall and William James, leading American psychologists at the time, had as one of their students, Edward Thorndike, who enthusiastically applied the new scientific psychology to the control of learning. In his still influential book, *Principles of Learning* (1921) Thorndike suggested that learning would occur if subject matter were carefully refined and sequenced and students appropriately reinforced. His popular prescription for intense practice as a condition of learning remains popular today.

Educational theories advocating the scientific control of human behavior reflected larger reform efforts in society and business after the turn of the century. Frederick Taylor, an industrialist had developed a method for studying the movements of workers on assembly lines and through a process of measuring and control, speed up production. Eliot Eisner writes about the scientific managerial approach as it relates to workers:

> *What one sees here is a highly rationalized managerial approach to the production process. The worker's job is to follow the procedures prescribed. In this system, individual initiative and inventiveness by workers were regarded as sources of error, like sand in a motor, they impeded the operation of a smooth running machine that depended on adherence to formula"*
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> p. 10, Eisner (1994)

When schools faced criticism in the early 1900's related to "inefficient" practices and poor learning by students they turned eagerly to scientific management as a way to improve. This standardization model remains attractive today and can be seen in the 1990's school reform efforts, e.g. the call for a standardized curriculum, *cultural literacy,* (Hursch, 198?) and specific, identical student outcomes.

2. An Alternative Scientific View

Like Thorndike, John Dewey, was also interested in the application of science to educational practice. However, unlike Thorndike, his scientific views were influenced not by connectivism but by an approach to the study of human organisms made popular by Darwin. As a result of this study, Dewey saw learning as an activity driven, not by reinforcement, but by the learner's sense of disequilibrium when presented with new experiences and ideas. For Dewey if real growth was to occur the student must want to learn and be active in the learning process. He argued that the traditional reinforcement of information-- given by the teacher, memorized and given back by the child --led only to superficial learning. The job of the teacher was to create a classroom in which the child would be presented with problematic situations which she/he would be motivated to resolve by learning. While Dewey's thinking did not influence the early development of instructional technology for a variety of reasons, his work served as an alternative framework for the study of learning through out the 20th century.

3. The Origins of Instructional Technology

Perhaps one of the reasons that Thorndike's views regarding learning came to dominate instructional design was the political situation in which the United States found itself as it faced two world wars. The country had a need to rapidly train military personnel. The training required was concrete and sequential, such as how to assemble an M-1 rifle, and could be easily described and arranged in step-by-step fashion. The rapid growth of audiovisual tools during the first half of the century also made it possible to tap the advantages of using sound and visualization for the design of the required training. The resulting training materials could then be used over and over successfully, without the need for extensive teacher preparation.

Robert Gagne is his book on the foundations of instructional technology (1987) describes early industrial technology as the confluence of the scientific study of human learning practiced by Thorndike and his followers and the availability of new technologies. The technologies of interest included both procedures and tools. New techniques, such as programmed learning tied to the use of audiovisual materials, were conceptualized as a way to increase the precision with which the learner is appropriately stimulated and thus increase learning. Such materials were easily replicable and usable in far away locations without additional teacher training. Much of the training related to military objectives was accomplished with speed and precision using these methods.

Extensive research around these early audiovisual experiments helped to define instructional technology as an attempt to provide "conditions for effective learning" (Gagne, 1987p. 3) . Growth in the field came from work in two areas 1) research on human learning, most recently human information processing, and 2) research and development designed to increase the capacity of instructional technology to provide better strategies for learning, exemplified in intelligent tutoring systems (ITS). These two fields, the study of optimal conditions for human learning and the use of well-developed procedures and tools, combined into what is now generally accepted as "a systems approach for designing instruction" (Association for Educational Communications and Technology, 1977). Within this systems approach increased emphasis has been put on improving the accuracy of the procedures involved in defining learning tasks, learner characteristics and needs, conditions for optimal implementation, and the tools and procedures needed for managing the instructional design process. However, within this paradigm no question are asked about the purpose of learning or the social context in which it is to occur.

The systems approach received additional support and funding from the federal government during the 1950's as a result of America's reaction to the Sputnik launch. In response to what was perceived as an educational crisis, Americans called for training and education which they believed to be scientific, systematic, rational, and reliable. Instructional technology had served the nation well during the war, why couldn't it also lessen what was perceived as a gap between American students as potential scientists and more scientifically skilled students in other countries, especially Russia.

4. Influence of Instructional Design on Public School Practice

A variety of instructional systems theories have had a profound and persistent influence on educational practice in K-12 settings. Several examples of these approaches will be discussed in the next section including programmed learning (Skinner, 1958), instructional objectives (Mager, 1962), conditions of learning (Gagne, 1965), mastery learning (Bloom, Madeus, & Hastings, 1981), and the work of Madeline Hunter (1967) in popularizing these instructional theories.

4.1. Programmed Instruction

B.F. Skinner, the father of operant conditioning, is usually credited with the development of programmed instruction. In his classic 1954 article, *The Science of Learning and the Art of Teaching*, Skinner described the conditions of the typical classroom as particularly adverse to learning. A single teacher can not individually and appropriately reinforce thirty or more students at the same time.

In this article Skinner first conceptualized a teaching machine for the classroom for use by individual students. This machine could present information, reinforce appropriately and then branch to the next level of difficulty depending on the individual's performance. The roots of computer-assisted instruction can be easily seen in Skinner's teaching machine.

4.2. Task Analysis and Behavioral Objectives

In order to fully implement programmed instruction two other areas of development were needed, task analysis and behavioral objectives. Task analysis is the process of identifying the tasks and subtasks that must be performed in order to complete a task or job. The concept of task analysis was applied to general education in early work by Frank and Lillian Gilbreth, expanded by Robert Miller (Miller, 1953) and utilized by Gagne (1987) as part of his description of the hierarchical nature of learning.

Methodologies associated with programmed instruction also required the identification of specific, observable behaviors that were to be performed by the learner. While objectives were advocated in teaching as early as the 1900's, Ralph Tyler has been called the father of behavioral objectives since he suggested as a result of his famous 8 year study of schools (1975) that many of the problems of instruction seem to be related to the fact that schools did not specify objectives, and that teachers and students were not aware of what they were supposed to be learning. However, the major implementation of behavioral objectives occurred only after Benjamin Bloom and his colleagues published the *Taxonomy of Educational Objectives* (1956). Even then, behavioral objectives were not widely used in practice until the publication of a small, humorous book by Robert Mager, *Preparing Instructional Objectives for Programmed Instruction* . This book has since been republished as *Preparing Instructional Objectives* (1962) and is still widely used today in both teacher education and training technologies. Robert Mager provides an excellent introduction to his book:

> *Before you prepare instruction, before you choose materials, machine, or method, it is important to be able to state clearly what your goals are. This book is about instructional objectives. In it I will try to show how to state objectives that best succeed in communicating your intent to others. The book is NOT about the philosophy of education, nor is it about* who *should select objectives, nor about* which *objectives should be selected.*
>
> Mager, 1962, p. viii

This is a very interesting little book which one reads in the manner of programmed instruction. Every aspect of the preparation of terminal behavioral objectives is well outlined and the reader is asked frequent questions the answer to which determines one's path through the book. After completing this book, the learner will be able to develop complete and precise objectives which define clearly the *terminal behavior* to be displayed by the learner, the *criterion* or standard by which the behavior will be evaluated ,e.g. 70% items correct on the test, and the *conditions* under which the behavior will be displayed.

One of the barriers to implementing programmed instruction and behavioral objectives in schools was the current organization of schooling. Classrooms were not organized to support individualized learning. Benjamin Bloom developed a method for reorganizing instruction to allow for more individualized learning which became known as mastery learning.

4.3. Mastery Learning

Bloom's method is based on the idea that the learner will succeed in learning a task if given the exact amount of time he or she needs to learn the task. Bloom was a passionate opponent of the common educational practice of assuming that only about a third of the class will learn the material taught suggesting "this set of expectations, which fixes the academic goals of teachers and students, is the most wasteful and destructive aspect of the present educational system" (Bloom, Madeaus and Hastings, 1981, p. 51). Bloom suggested a variety of strategies that can be used in classrooms to provide conditions for mastery learning including the use of tutors, small group study, peer tutoring, programmed instruction, audiovisual materials and games. Research by Bloom and others in many countries demonstrated that slow learners can indeed achieve as much as faster learners when given the opportunity(Block & Anderson, 1975; Bloom, 1976; Yildiran, G. ,1977)

4.4. The Conditions of Learning Model

Robert Gagne is best know for his development of a model of instruction based on human learning. Prior to Gagne, learning was often conceptualized as a single, uniform concept. No distinction was made between learning to load a rifle and learning to solve a complex mathematical problem. Among Gagne's contributions was the notion that there are various types of human learning and that each of these types of learning require different kinds of instructional strategies. For example, while Thorndike advocated continuos practice as the key to learning, Gagne suggested practice was effective only for certain types of learning, such as typing or playing ball which involve kinesthetic learning. The learning of cognitive strategies for problem solving is a very different type of learning, requiring different instructional strategies and conditions. In order to learn cognitive strategies, the learner must be presented with and assisted in solving puzzling problems. For this type of learning, practice without a change in perception can be counter-productive.

Gagne's development of a model of human learning foreshadowed later discoveries of human information processing and added significantly to our understanding of stages in cognitive processing and their relationship to instruction. He argued that an understanding of the characteristics of and functions of short term and long-term memory were important for instructional designers. Students will not be able to retrieve learning from long-term memory for later use if they are not assisted in incoding new concepts it in meaningful ways during the initial learning experience. These ideas influenced instructional designers to include the cognitive needs of the learner but within the same top-down instructional approach.

4.5. Instructional Theory Into Practice

Many educators found in Gagne's work a foundation for addressing the instructional problems found in schools, perhaps none more so than Madeline Hunter. She suggests that her strongest contribution to education was not additional theory, but the development of the technologies needed by teachers to implement new theories of learning. She describes her purpose in the opening to one of her many publications.

> *Psychological knowledge that will result in significantly increased learning of students is now available for teachers. In most cases, this knowledge remains unused because it is written in language that takes an advanced statistician to decode , or is buried in research journals in university libraries. This book is one of a series written to make this important knowledge available to the classroom teachers.*
>
> Hunter (1967), forward

In her years as a professor at UCLA and a prolific writer she had a significant influence on educational practice. Students in teacher education programs over the last 20 years, studied her writings and videos and inevitably learned to write precise instructional objectives, engage in task analysis, design appropriate guided and independent practice and write for their student teaching supervisors six-step lesson plans. Hunter's work provided the basis for a popular approach to remediation of students who were not doing well in school. The model, diagnostic-prescriptive teaching was widely adopted by federally-funded programs designed to provide what became known as *compensatory education* for children from the lower socio-economic classes. It was theorized that basic skills teachers trained in Hunter's instructional technologies would be able to quickly and efficiently remediate the learning difficulties of those children who had received inequitable educational opportunities.

5. Commonalities

Both traditional instructional design and design aided by insights from cognitive and humanistic pyschology had in common certain characterisitics which will be described in this section. It is these commonalities which prevade current instructional practice and which may limit the design of computer-based collaborative learning environments.

5.1. An emphasis on Method or Technique

All of the designs for learning discussed thus far reflect a technological approach to learning. The aim is to avoid philosophy as Mager suggests when he writes that his book is "NOT about the philosophy of education, nor is it about who should select objectives" rather, one must learn the techniques required to make learning more efficient. The value or importance of what is to be learned is not considered. Questions are not asked, as Dewey might have asked them, about the kinds of learning that would be useful to the larger society. As Dewey suggested, one can learn to be a better thief but such learning, however rapid, might be socially undesirable, an example of what he termed *miseducation..*

5.2. Psychology and the Individual Learner

In addition, the instructional design models described focus solely on the individual learner. None of the models consider the social or cultural context in which learning is to occur. The only relationships which are well-described are the relationship between the teacher or the teaching machine and the individual learner. This reflects the dominant influence of American individualistic psychology on both education and the development of instructional technology. Thorndike stressed the need for individual practice and reinforcement for learning to occur. Skinner proposed a system of individualized programmed instruction which would focus specifically on the reinforcement needs of each individual in order to increase learning in schools. Bloom with mastery learning provided an approach to teaching which would allow some reorganization of instruction in classrooms in order to increase the likelihood of individualized learning. Diagnostic-prescriptive teaching, task analysis, and individualized remediation were all based on the individual, much like a doctor's prescription for an individual patient.

5.3. Focus on Content

While larger questions about the social value of what should be taught were not asked, each of these models was designed around the assumption that the important act in school was the learning of content--facts, figures, and concepts. In terms of Dewey's original question (1905) concerning the distinction between the focus on the child versus the focus on content, instructional technology is grounded in the content to be taught, not the needs of the learner and group, or the social context in which the learner is situated. Traditionally, instructional designers have asked themselves: What are the concepts to be learned? How should they be presented and sequenced? What ideas need to be taught prior to others? What media can be most useful in presenting each concept? One can only reflect on the meaningfulness of content with context.

6. Alternative Conceptions of Learning Relevant to Design

Perhaps the most eloquent critic of the technological approach to education is Eliot Eisner (1982,1994) Eisner, whose work is well-grounded in the work of Dewey with whom he agrees that there is an important distinction between education and learning. In his discussion of different philosophical orientations to education, Eisner identifies the technical approaches discussed in this paper as unconcerned with the larger purpose of education. He also describes the limitations of teaching to objectives which are an essential element of current instructional design practice. Eisner describes the result of an exclusive use of behavioral objectives which breaks learning into small, manageable pieces. These pieces of learning are easily reinforced and measured. The problem is that students while mastering each of these pieces is unable to put the pieces together and apply them to new situations. For example, a student may be able to name each of the vowels with 100% accuracy but not be able to distinguish between vowels in new words. Eisner argues, in addition, that there may be some very important goals of education, such as an appreciation of the arts or the valuing of open-minded skepticism in science, they are not easily broken down into small units of behavior which can be taught and reinforced. Finally, he proposes that the evaluation of students has and always will drive the curriculum. So long as we evaluate students in terms of easily measured small units of behavior students will only learn such small units of behavior. If we want students to gain problem-solving skills we will have to evaluate and value problem-solving, a type of learning which, as Gagne pointed out, is not learned by rote practice.

7. Training vs. Teaching

It was desirable in many of the situations in which instructional technology evolved, such as the need to quickly train soldiers during World War II, that teaching and learning materials not require extensive training and involvement of on-site teachers. Yet there is a real danger in continuing to conceptualize teachers as factory workers. In fact, one can argue that it is this conceptualization that may be partially responsible for the fact that so few teachers have access to telephones and thus to Internet connections. After all, factory workers don't need telephones.

However, current educational reform movements recognize the important role of the teacher in supporting changes in instructional practice in classrooms. Without changes in teacher behavior, the best possible curricula will remain unused and have little or no effect on student learning. Teachers have always had a significant influence on student learning. As the diversity of our population and the complexity of what students need to know increases, teachers who are capable of designing learning appropriate for their community and the students who will work in an information age become increasingly important. Any instructional design theory in which teachers do not have a central role as designers and facilitators of learning will become less and less useful. The tasks of the teacher have become increasingly complex and the staff development needed is no longer one shot training programs or providing teachers with so-called teacher-proof materials, but rather continous opportunities for professional development that occur in the context of the everyday work of the school.

8. The Social Context for Learning

Traditional approaches to instructional design assume that knowledge is independent of the situations in which it is learned and used. More recent research on learning in everyday situations and different cultural settings suggests the knowledge is not an independent phenomena, but situated in the activity, context and culture in which it is developed (Brown, Collins, and Duguid, 1988). An understanding of the need to connect learning with doing leads to a fundamentally different view of teaching and learning than that advocated by current instructional design practices. Tharp (1989) and others have suggested that learning is a process which occurs in social interaction. For example, Tharp and Gallimore (1976) describe how Hawaiian children who are used to working with peers may be perceived by their teachers as possessing low academic motivation rather than as seeking their own preferred learning environment which stresses peer cooperation. Therefore an important task in the design for learning is to make the organizational structures of schools ones in which students from a variety of culutures will be productive and engaged participants.

The purpose of this paper was not to develop a theoretical framework for such communities of learners. Work by Brown (1994), Roschelle, J. (1994) and many others attending this first international conference in computer-based collaborative learning has already begun in this direction. Rather, this paper was written to provide insight into the paradigm within which instructional design operates. This paradigm is particularly pervasive in current school practice, especially as it applies to the implementation of educatonal technology. In much of the computer education community we are still building and selling Skinner's teaching machines. A recent book, *Computers as Cognitive Tools* provides what one reviewer describes as a "dialectic of instructional technology" (Koschmann, 1994) between those who would design better controls and models for learning, the roots of which can be found in Thorndike, and those who believe in a social constructivist approach, origins of which can be found in Dewey. An expanded concept of instructional design that includes the purpose of education, the need to teach the person as well as the content, and the importance of the social context of learning is required before we can implement computer-based collaborative learning for the children in our schools.

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*Desi*gning for *L*earnability (*DesiL*): An Engine for Informing the Design of Easy-to-Learn Microcomputer Interfaces

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Abstract

Modern software design is focused at maximizing the usability of its products [1, 2, 3]. Once the domain of technical experts and "guru's, we are now told that computers are "for the rest of us"[4].

However, usable software designs still mandate some specialized training in their use [3]. As computers become more prevalent in the workplace, individuals must both maintain their current level of productivity while learning new methods of performing tasks they had previously done either manually or using a different computer software application. Software that minimizes learning time could be of substantial value to deadline pressured workers who must take advantage of advancing technologies but do not have access to special training.

DesiL (*Desi*gning for *L*earnability) is a methodology for informing the design of microcomputer software, that may permit a designer to produce both usable and more easily learned software applications. This methodology is non-deterministic in that it does not make decisions for a designer, but rather informs a designer's options toward creating software that may be more easily learned by the end user.

Keywords — Learnability, training & education, human-computer interface design, human-computer interaction, ethnomethodology, qualitative research.

1. Introduction

The capabilities and flexibility of modern computers is an awesome testimony to the ingenuity of 20th century technology. Television and print advertising declares that mastery of computers will bequeath "David over Goliath" power and an edge over business competitors or fellow students. Once learned, computers provide "one button" (or one mouse-click) access to unlimited skills and knowledge. Once the domain of technical experts and "guru's," we are now told that computers are "for the rest of us" [4].

In the process of making a computer for the rest of us, engineers, scientists, and psychologists have focused much study toward making them more "usable" [2, 3, 5, 6]. However, despite their "easy to use" status, the task of becoming a more efficient computer user has remained a difficult and sometimes threatening task [7]. Thanks to current practice in HCI, *being* a computer user has become an easier task, but the process of *becoming* a computer user, or a more efficient computer user is still an awesome task.

Although publishers of computer software are aware of the need to make their products easier to learn and use [2, 6, 8] current strategies of software design are not always successful in producing an "easy to learn" software application [9]. Evidence of this is seen in the many different "helping" mechanisms computer software publishers have invented including printed manuals, on-line "help" glossaries (software versions of printed manuals), hypertext help systems [6] and on-line demonstrations [10]. Additional evidence is supplied by the successful third party and "self help" publishing industry offering literally hundreds of book, videotape and software titles to assist a computer user in learning to use computer software. However, even the existence of these aids cannot guarantee that a computer user will correctly interpret the instructions as intended by their author [11].

2. Software Design Methodology

DesiL is based on the theoretically and empirically grounded notion that learning is most likely to occur when material to be learned is semantically attached to something already known [12, 13, 14] and that incorporates several parallel "modes of representation" tuned to the intended learner 12]. For this reason, the use of visual and linguistic analogies and metaphors are commonplace in the design of modern software interfaces [5, 8, 14, 15, 16, 17].

Design methodologies exist that bring potential users of software into the software designers world to participate in the iterative process of designing interfaces [18, 19, 20]. These methods permit the designer to solicit actual users for their tacit assessment of the usability of a professionally designed interface

However, despite evidence of these methods advantages to creating "usable" software, they remain largely under the control of specially trained "designers" who may unknowingly limit their design efforts to the "inner environment" [21] of the task domain, and ignore the "outer environment" [21] represented by the user's perception of the task and their perception and interpretation of the context in which it is performed. Because such designs were created out of their context of use, they may be more difficult to learn in the milieu and perhaps chaotic context of actual use.

Newby [22] and Cool's [23] research implies that other factors are necessary for the creation of "learnable" software. These factors transcend the notion of learning promoted by cognitive-science and suggest that a more learnable computer interface should accommodate a computer user's current knowledge, experiences, and perceptions and interpretations of a computer based task and its context of use. Cool [23] delineates a three part design focus that incorporates and extends both "inner" and "outer" [21] factors of the computer user, their environment and the task to be performed, including contextual and linguistic dimensions delineated by Bruner [12] and Vygotsky [24]. This research implies that a computer user's current knowledge, experiences, and perceptions and interpretations of a computer based task and its context of use may be discovered and delineated using ethnomethodological research techniques, and that these findings may be used to inform the design of software that is not only easy to use but also easy to learn.

2.1. DesiL Methodology

DesiL is based on sociologically grounded ethnomethodological inquiry in which a software designer observes and conducts interviews with members of a population in situ to determine what *methods* they use to perform their daily duties. Ethnomethodology has as its purpose to "analyze everyday activities as members' methods for making those same activities visibly-rational-and-reportable-for-all-practical-purposes" [25].

Traditionally, ethnomethodology has confined itself to the understanding of singular events with the belief that, because the circumstances surrounding events are fundamentally non-repeatable, so the analysis of these events are non-generalizable in the classic sense. However, it is becoming increasingly acceptable to perform ethnographically grounded studies of work sites with the intent of informing the design of human-computer interactions [26, 27, 28, 29] DesiL continues this effort but focuses on using the ethnomethodological data for improving the "learnability" of a microcomputer interface.

In particular this study was performed through the onsite observation of workplace activities and guided and open ended interviews similar in format to the anthropologically grounded "elicitation interview" [30, 31] and the "20 statements test" [32].

Field notes and interview transcripts were analyzed using the constant comparative analysis technique [33]. These analyses were used to create "contact summaries" [34] of the observations and transcripts and as guides in coding the data to describe the participant's perception and interpretation of specific human-computer interaction tasks and how these were effected by the context of their work.

These codes were used by the software designer during initial design phases, to better "fit" the evolving design to the participant's understanding of the task domain and context of work.

3. Research Venue and Population

This study was conducted with four office workers in an administrative office located in a Southwestern, USA university. This office has recently been switched from using stand-alone microcomputers, paper-based files and remote access to the university's mainframe computer to being connected to a new Local-Area-Network (LAN).

This office is comprised of five staff members and their supervisor, and is dedicated to administrating the college's undergraduate, transfer student and post baccalaureate enrollment into teacher certification programs, college of education student graduations and to assist in the data processing necessary for assigning student teachers to local schools for fieldwork experience. The transition of data processing tasks to a LAN-based database management system introduces a small but "authentic" problem for these workers, the transfer of their knowledge and understanding of an "old way" of doing their jobs, to a "new way" of performing the same jobs with different tools.

3.1. The Participants

With the exception of the office's supervisor, all staff members of this office are adult women ranging in age from 28 to over 50. The research participant's formal instruction in the use of microcomputers has been limited to "short courses" in the use of applications software (word processor, spreadsheet, ...) at the university's computer center. Currently, each participant uses several common application software packages in her individual job duties.

Each of the participants in this study has a distinct "specialization" in the office. Although each is capable of filling in for one another to a limited extent, for the purposes of this study, each person's individual responsibilities do not overlap. As I have observed, the many and varied responsibilities of this office can occasionally result in scenes similar to hospital "triage" as students come and go, with their own individual questions and crises.

4. DesiL's Contribution to Software Design

As indicated, DesiL is a non-deterministic design methodology. This means that interface designers are free to analyze and interpret the field based data in terms of their own personal design philosophy and in conjunction with accepted industry and psychologically grounded standards for HCI design [6, 8, 16, 19, 35]. However, from the ethnomethodological inquiry, an improved understanding of the context of human-computer interaction tasks may be gained, and used by the designer to more fully "tune" his or her HCI design for the target population.

In particular, during our conductance of this research, it was noted that the qualitative data collection and analyses greatly facilitated the conductance of learnability focused "cognitive walkthroughs" [2, 36, 37, 38] of interim interface designs before they were ever committed to code. It is in this phase of the design process that we see the greatest benefit for the DesiL design methodology. Additionally, the effectiveness of such a priori learnability checks may improve as a designer becomes more accustomed to the use of DesiL.

An additional benefit of the ethnographically based DesiL methodology, over other methods for ensuring software learnability [2, 36, 37, 38] is that it does not require any special training for the designer other than an "eye" for the [33] and a diligence in data analyses!

4.1. Testing of Interfaces Designed with DesiL

As of this writing (6/95) final analyses of the HCI design has not been completed. A combination of both qualitative and quantitative data collection and analysis methods is used to assess the learnability of prototype interfaces.

Verbal protocol [39, 40, 41] and elicitation interviews will be conducted with each participant at two day intervals following installation of the software. Resulting field notes and interview transcripts are analyzed for the existence of "awareness contexts" [42] and "flow" states [43]. Awareness contexts delineate a taxonomy that indicates a person's level of understanding of their partner in an interaction, and "flow" is a psychological construct indicating a merging of a person's skill and knowledge of a situation.

Additionally, the software has been designed to unobtrusively collect each individual user's software command inputs. Tracking discrete command inputs during each session with the software results in an "action transcript" of each human-computer interaction. Stochastic analyses performed on these "action transcripts" permit the identification of patterns of interaction as the participants use the software. In terms of this research, the existence of a rapid decrease in entropy over time, and a statistically significant regularity [44] in these "action transcripts" is considered as evidence of an easily learned interface design.

5. Contribution to the Discipline

The discipline of computer software design has two purposes: (a) to codify a set of instructions to guide a computer in the performance of some task and (b) to give a computer user relevant control over that task. By better understanding how persons bring their existing contextual knowledge and skills into an HCI and use them in completing their duties, this research may inform software designers on how to better design and develop their products to accommodate user's perceptions and interpretations of that software. The resulting products may be easier to learn.

Additionally, the use of both qualitative and quantitative data to mutually support each other, may further inform the practice of software design for learnability by adding a unique methodology to the researcher's set of tools for assessing software designs.

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Collaboration and Learning with Logo: Does Gender Make a Difference?

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Abstract

The present study represented the final in a series of five which explored the performance of children in Logo tasks while they worked in one of three gender pairs (girl, boy or boy/ girl). Differences in performance based on the gender of the pair had been apparent in the early studies when specific types of tasks were presented as initial experiences in the new domain. The present study analysed the strategies and interactions of 30 pairs of children (mean age 7 years 3 months) in relation to three sets of tasks. The children worked with the screen version of Logo (LCSI) in tasks that required them to make accurate copies of given (Logo) figures and to direct the turtle up a path to a destination The results revealed that when the copy task was presented first and followed by the track task there were no significant differences in performance in terms of accuracy or efficiency of moves made in order to reach the end of the path. This was a contrast to previous findings when the track task had been presented first. The current research illustrated that performance was moderated by the type of strategies that were deployed and the nature of the collaboration of the pairs.

Keywords — Learning with computers, gender, performance with Logo.

1. Introduction

Recently there has been an increase in pressure on early childhood educators from parents and administrators to incorporate computers and other forms of technology into early learning environments. Yet the information that is available to early childhood educators pertaining to the perceived benefits to learning, of the new information technologies, and indeed, descriptions of how they can be used in early childhood settings, is scarce. Thus, it is not surprising to find that most are still sceptical that the financial outlay is not matched by the perceived educational benefits. Early childhood settings are characterised by active exploration, talk and collaborative learning partnerships. The computer is often viewed as being developmentally inappropriate for young children because their applications focus on the two dimensional and abstract concepts, programs that encourage individual participation and thus no opportunity for social interactions and engagements that can foster language and cognition. The present research sought to provide information to early childhood educators pertaining to learning with technology and to highlight some of the ways in which teachers and learners can facilitate cognitive and social aspects of learning, within a specific computer environment; Logo.

In most of the studies of young children exploring with Logo, their performance, whether working individually, in pairs or small groups, has been described and related to either specific methodological issues pertaining to curriculum and teaching (e.g Hawkins, Homolsky & Heide, 1984; Noss, 1984;) or to cognitive theories of learning (e.g. Clements & Nastasi, 1985, 1988; Webb, 1982, 1984). Only a limited number of these studies have considered performance with reference to the gender composition of pairs, small group or indeed individuals. (e.g Gunterman & Tovar, 1987; Hoyles and Sutherland, 1989; Hughes, Brackenridge, Bibby & Greenhough, 1988)

Hoyles and Sutherland (1989) noted differences in the programming styles of boys and girls and also differences related to the nature of the collaboration and attitudes while working. However, at the end of a three year project found no gender differences related to the student's ability to use the ideas of structured programming when working on a well defined task, the ideas of a variable and either a top-down or bottom-up approach to planning. They also indicated that a girl was "more likely to share her problem with her partner, her representation of the problem, and her ideas for problem solving." (p. 171). They provided useful advice about the dangers of coming to quick and superficial conclusions about supposed gender differences on the basis of short term performance and warned against the use of slogans such as "Girls do not plan and boys do not collaborate in their computer work or boys are better than girls in programming" (p. 177) They enforced the idea that statements need to reflect the context in which the activities have occurred and to consider development over a series of tasks and time.

Studies that preceded the present research (Yelland, 1989, 1993, 1994a, 1994b) revealed that young children's (6 and 7 years) performance in Logo tasks was moderated by factors such as the task structure, the style of interaction in dyads and personality characteristics that affected the way in which the problem was solved. The results of these studies also indicated that performance was differentiated according to different levels of operation to task solution which were the result of a number of features, such as comprehension of the task requirements, the selection of appropriate strategies for solution and the application of selected executive processes. The use of such processes ensured a more effective level of task solution that reflected a greater level of sophistication in the application of problem-solving skills. The studies highlighted qualitatively different levels of performance, ranging from naive to knowledgeable, that were distinguished according to the types of processes that were deployed in the problem-solving context, and the influence and application of prior knowledge relevant to task solution. The studies also indicated that performances were differentiated on the basis of gender according to specific criteria and related to certain types of tasks. However, with experience in the domain and with changes in tasks design and presentation, such differences disappeared. They also highlighted that collaborations varied according to the gender composition of the pair in initial experiences in a new domain with specific types of tasks. Girl pairs frequently sought more information from each other and used verbal strategies to work through their problem-solving. This was contrasted with the style of interaction of boy and boy/ girl pairs who tended to make more independent moves and talk often centred on disagreements rather than clarification of ideas and strategies.

2. Method

2.1. Sample

The children who participated in the study were 60 children in Year 2 of a State Primary School in a suburb of the city of Brisbane. The mean age of the children was 7 years and 3 months. All of the children had used a computer in the school context and ten had a computer at home. None of the children had previous experience with Logo.

2.2. Procedure

The study took place over a period of 6 weeks in the third term of a four term school year. There were four main sets of events that constituted the research design: the pre observation activities, the preliminary activities, the copy tasks and the path task.

Pre-observation activities

The pre-observation activities were designed to obtain information about the children's previous experience with computers and their abilities in mathematical operations.

Playing Turtle

Before the children attempted the activities on the computer, we "played turtle" in the playground. The children participated in activities that required them to give and follow directions, such as moving forward or back and turning left and right in order to reach specific points.

Preliminary Activities

The children were introduced to the Apple IIe computer and a one key version of LCSI Logo. Each session was videotaped so that an accurate record of the children's performance could be obtained and was later transcribed for the data analysis. In the initial session the children were introduced to the four basic commands together with various input numbers and "housekeeping" commands were demonstrated (rub out, home, clearscreen, space bar, pen up, pen down). They were then given the opportunity to play and explore with these commands for 10 minutes.

In the first three activities the turtle had to be directed so that it would face a tree. The moves that would achieve this were turns of R 90 (or L 270), R 40 (L 320) and L 120 (R 60). Next, the turtle was placed 100 steps away from (a drawing of) a tree and had to be directed to it. No turns were necessary in order to achieve this. Then, the children had to direct the turtle up a path consisting of two right angles and three "stretches". The optimal moves to complete this task were: F 60, R 90, F 70, L 90, F 40. Finally the children had to try and make an accurate copy of three items each of which had two sides of 50 turtle steps, the first was a right angle, the second an obtuse angle (130°), and the third and acute angle (60°)

Copy tasks

The children were presented with two items to copy: a flag and a house. As with the copy task items in the preliminary tasks they were told that they has to make the turtle draw the items as carefully as possible, so that they would look like the picture on their screen.

In scoring each of the items it was apparent that the number of moves made to complete the first five (preliminary) items were appropriate together with a record of the time taken and the number of moves that were made off the path. However, in the copy tasks it was evident that this was not appropriate since accuracy of the copy made was more important than the amount of moves made. Thus, a scoring system that was developed in previous research was used. A score was obtained for the length and angle based on the deviation from the perfect copy. For any combination of moves that produced the desired length of the segment and the (total) correct amount of turn to produce the angle, the inaccuracy score was zero. A score of one was given for deviations from these parameters for each unit that the deviation varied from the desired amount.

Path task

In the path task the turtle had to be directed up the path to the baker's shop, situated at the end of the path. The path consisted of five "stretches" and four turns. The following instructions were given:

1. "You have to take the turtle up the path to the bakery, so that it is just in front of the door, in as few moves as possible." This instruction was then confirmed.

2. "You have to stay on the path. If the turtle goes off the path you have to try and get it back on the path as soon as possible."

3. "I want you to work together to do this and help each other. You can talk to each other and it may help to think about when you played turtle in the playground."

Analysis of interaction

In a previous study (Yelland, 1994b) categories of interaction were generated in order to attempt to characterise the nature of problem-solving strategies that the pairs of children engaged in. These were incorporated into the present study and in the initial analyses only the behaviour for the path task were to be transcribed and coded according to the following categories in order for a comparison to be made with the previous work. The categories were:

1. asking for information/explanation
2. offering information/explanation
3. agreeing with the information/explanation
4. disagreeing with information/explanation
5. ignoring the information/explanation
6. deferring to the information/explanation
7. asking for a proposal
8. offering a proposal
9. agreeing with the proposal
10. disagreeing with the proposal
11. ignoring the proposal
12. deferring to the proposal
13. making supportive comments
14. making non supportive comments
15. independent moves
16. tension release
17. non task or incoherent language.

These categories catered for all the behaviour that was recorded on videotape and transcribed in order to facilitate analysis. Categories 3 to 6 and 9 to 12 reflect *immediate responses* to the offer of information or explanation, and the offer of a proposal respectively.

3. Results and Discussion

3.1. Preliminary Tasks

The mean scores and standard deviations for the number of moves made, time taken, and inaccuracy scores for each of the preliminary task items for each of the gender pairs were subjected to a one way ANNOVA in order determine if there was a significant difference between the groups on these parameters. No significant group differences were found on any of the items. This was a contrast to previous research which had found differences on the simple path (two right angles) and the time taken to complete all of the items that comprised the preliminary activities.

3.2. Copy tasks

Mean inaccuracy scores, standard deviations for the length and turn aspects of the copy tasks were calculated for each group (girls, boys and boy/girl). Again a one way ANNOVA was applied to the data to determine if there were any significant differences between the gender pairs on each of the two items, but none were evident.

3.3. Path task

Finally, the mean scores and standard deviations for the number of moves, the time taken and the number of errors (moves off path) made in order to complete the task were determined. No significant differences between the groups were found on this data when the ANNOVA was administered.

3.4. Analysis of interaction

The interactions for the path task were coded by using the transcription from the video in conjunction with watching the videotaped session. A colleague verified the coding for three pairs, one of each gender, by categorising each interaction on the transcript. It was vital to conduct the validation in this way so that there was inter-rater agreement on each type of behaviour. When this was done the number of interactions that differed were counted and converted to a percentage of the total number. The level of inter-rater agreement was 87%.

An ANOVA was conducted on the data and this revealed significant differences on four of the variables. Newman-Keuls post hoc analysis showed that the differences were between the girl pairs and both the boy and boy/ girl pairs with respect to the frequency of:

- offers of information / explanation ($p < 0.01$)
- asking for proposals ($p < 0.01$)
- offering proposals ($p < 0.001$)
- agreeing with proposals ($p < 0.01$)

In the path task the girls engaged in these forms of interactions more frequently than the other pairs. This represents a similar pattern of behaviour that was found in the previous study when the path task was presented to the children before the copy tasks and when there were significant differences in performance between the girls and the other pairs in terms of the efficiency of moves and the time taken to complete the task.

4. Conclusions

Thus, the study highlighted that the nature and sequence of task presentation as well as the type of variables that are considered as being measures of performance are important when describing the nature of performance in Logo tasks. Previous research (Hughes et al, 1988) had suggested that the performance of girls in Logo tasks were inferior to that of boy or boy/ girl pairs in terms of task completion and reaction to problem situations. In an attempt to explain this occurrence, the studies which began this series attempted to sequence Logo activities so that an explanation of performance over time and tasks could be generated. The results revealed that if performance was only considered in terms of efficiency of moves and time taken then indeed the performance of girls and boys was different, but only for track type tasks as initial experiences in a new problem-solving domain. Such differences disappeared over time and when performance was viewed in terms of accuracy there were no significant differences between the gender pairs even though the girl pairs often made more accurate copies of simple items with Logo. Previous research (Yelland 1994a, 1994b) indicated that in initial experiences with Logo affective processes seemed to moderate the performance of girl pairs as well as the lack of metastrategic processes (Davidson & Sternberg, 1985). In the present study this was not apparent and the reason seems to be related to the sequencing of the tasks, whereby the copy tasks were presented to the children before the path task.

The research underscores the need to observe and describe young children's problem-solving behaviour in a variety of task types and over a reasonable period of time before coming to hasty conclusion that differences in performance based on gender are apparent or not. In the present series of studies it was evident that what distinguished performance was the application of metastrategic processes. The most salient feature was the nature of the discussions that took place before a move was decided upon. The most effective moves reflected an awareness of mathematical processes together with metastrategies such as monitoring progress effectively, responding to feedback from the system, reflection and discussion. This was evident in conversations prior to moves being made such as:

gg1: What shall I do first?
gg2: Well..... I think that it's about 50 forward.
gg1: Yes.... no .....wait....do you think it's half of what we did when we went to the tree, 'cos that was 100.
gg2: I'm not sure what do you think?
gg1: we don't want to go off the path....so let's try 40 to be safe
gg2: Ok! so just type f d space 4 0

The move is completed

gg2: Oh it needs to be more.... how much do you think? I think 20 more.
gg1: Ok f d space 20. (move entered and completed)
gg1 There ......now we have to turn, It's left isn't it?

Other pairs who were less efficient, in terms of number of moves made and the amount of time taken, often just proceeded with each move and slowly "edged" their way up the path or conversely went off the path and had considerable trouble getting back on again because they did not reflect on how they had directed the turtle into such a position.

The research also indicated that the Logo environment is a rich problem-solving environment in which young children can work collaboratively and engage in metacognitive activity that is characterised by a strong engagement with the tasks set. Future work can now concentrate on the nature of learning with Logo and attempt to describe the ways in which Logo experiences could be developed so that all children have the opportunity to participate in rich learning environments characterised by active participation and construction of ideas.

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Refining Knowledge in a Virtual Community: A Case-Based Collaborative Project for Preservice Teachers

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Abstract

This paper examines issues of integrating technology into teacher education. By looking at a case-based project designed to help preservice teachers at two United States higher learning institutions to examine and refine their beliefs about teaching and learning through collaboration via electronic mail, the study attempted to investigate how computer networks can be effectively used to enhance constructivist learning. Major findings include: (1) case-based projects promoted critical thinking and knowledge revision; (2) collaborative thinking and critiquing were affected by many factors—technology was only one of them; and (3) technology was more effectively learned when embedded in content-based projects.

Keywords — computer network, teacher beliefs, teacher education.

1. Introduction

Technology, particularly telecomputing technology, has been praised for its potential to facilitate collaborative learning activities [4, 6]. In a project utilizing computer networks to provide "teacher education students with hands-on opportunities to experience collaborative, constructive learning," [2, p. 149], the Teaching Teleapprenticeships (TTa) team found computer networks have several advantages: (1) time flexibility; (2) distance flexibility; and (3) immediate feedback. Additionally, Zhao [8], suggested that information on computer networks is less authoritative because it is easier to create and publish, thus making it easier to reveal the inadequacies of one's knowledge.

However technology, in and of itself, contains neither pedagogical nor content bias [3]. For instance the computer network can be used to transmit traditional instructional packages or used to promote cooperative learning. To use technology to support constructivist learning, the teacher must understand the precepts of constructivism. It is also necessary for teachers to be familiar and comfortable with technology so that they can focus more on the possibilities of the technology rather than being inhibited by their anxiety from exploration of its potential.

In light of the above considerations, we designed a case-based collaborative activity that is intended to help teacher education students: (1) refine their beliefs about learning and teaching; (2) experience a collaborative and constructivist learning project; (3) acquire skills with computer networking technology; and (4) develop a positive attitude toward medium-mediated communication.

2. Edpsycommunity: The Project

2.1. Participants

Participants were 68 teacher education students at two United States higher education institutions. One is a public research-oriented midwestern university while the other is a private four-year teaching-centered liberal arts college in the Northwest. Overall about 30 percent of the students had experience with email prior to the project. Most had used computers for word processing. About 5 percent of the students had access to the Internet at home. The rest had to go to a computer lab in order to use email and other network related tasks.

2.2. Procedures

The project lasted one semester. Initially, the participants were asked to write five essays analyzing a classroom case from different perspectives. For the first analysis, the participants were asked to analyze the case and provide a hypothetical action plan to cope with the problem situation based on their experiences and beliefs. This was intended as a vehicle for them to reveal their present beliefs. The second analysis asked the participants to provide an analysis and action plan for the same case using a Behaviorist perspective. The third one required analysis from a Cognitive perspective. The fourth one asked the participants to analyze the case from multiple motivational theories. The final essay requested students to again provide an analysis from a revised perspective of their own.

Halfway through the semester following completion of the second case analysis, we realized that the participants were not taking advantage of the system and collaborating as much as we had expected. We asked the participants to reflect upon the experience and solicited suggestions using the weekly email processing journal mechanism. Based on the feedback, we made the following adjustments: (1) split the large group into eight groups of 10 to 12 people equally divided between students from each section at Linfield and the section at UIUC; (2) gave longer time-gaps between assignment instructions and assignment due dates; and (3) discussed the importance of the experience. As a result of this change, only three case analyses were completed.

3. Results

Based on the 406 messages exchanged among the students during the project, students' weekly process journals (726 total), and interviews with six selected participants, we have the following findings to report. The findings are organized around each of the four goals we expected to achieve.

3.1. Goal One: Help Students Refine Their Beliefs About Learning and Teaching

To find out to what degree this goal was met, we categorized participants' case analyses into four groups along two dimensions: (1) basis of beliefs and (2) teaching approaches. After reading all the messages, we found that the participants generally based their analysis on two sources: their own learning experiences or a known theory. Therefore we first coded the messages into two groups: Experience-based and Theory-based. The second dimension was about the approach each student would take to teach the first class. Two distinguishable types were identified: Quasi-Behavioral and Cognitive-Humanistic. The coding was first completed independently by the two researchers. They then exchanged the results through email. When there was a disagreement, the two researchers discussed (over email) and reached an agreement. Table 1 summarizes the analysis of the messages.

As indicated in Table 1, Goal One was achieved for the most part. From the first to the last case analyses, we observed a clear shift of beliefs about teaching and learning. While the beliefs as revealed in the first case analysis reflect the students' own learning experience and a disposition toward teacher-centered and quasi-behavioral (assertive discipline type) approaches, beliefs revealed in the last case are more theoretically-based and cognitively-oriented.

Table 1. Distribution of Case Analyses.

Case #	Total	Basis of Beliefs		Teaching Approach	
		Experience	Theory	Behavioral	Cog-humanistic
1	51	46	5	48	3
2	48	43	5	48	0
3	50	11	39	0	50

The participants noted their changes of beliefs in their process journals. Almost every participant reported in their final process journals that as a result of the class, particularly the case-based project, they will teach differently. More tellingly, students began to think and discuss theories.

Technology or The Project: What Made the Difference?

Faced with these results, we asked ourselves the question: Would students have changed their beliefs without using the technology? The answer is yes because:

First, although we had expected that the participants would make use of the network to exchange ideas before they wrote up their analyses, the amount of exchange among the participants over the network was minimal. For the first two case analyses, every student posted their final drafts to the whole group. No single message was posted prior to their posting of the final copy, although there were seven messages commenting on the second case analysis immediately after the message was posted. After getting an unsatisfactory grade, one participant posted his revision of the second analysis to the group and solicited comments and suggestions before he turned it in for regrading. No responses were recorded on the network, and it is not known if he received any comments privately. Basically the first two case analysis were independently completed by each individual. The email only served as a bulletin board where the participants posted their final products. The technology did not make a big difference in the quality of the analyses.

Second, even though there was a tremendous increase in the number of messages exchanged among the participants before they began to write the third analysis, it is not obvious if that exchange had any impact on individual analysis. As mentioned earlier, due to the lack of collaboration during the first half of the semester, we made two structural changes: breaking the participants into smaller groups and allowing more time between assignments. Evidently the changes greatly facilitated the collaboration, at least in terms of the number of messages exchanged (from 0 to 139). However, a closer look at the content of these messages suggests that most (87%) of these messages were more confirming than challenging to the original ideas posted.

In summary, the result that the participants beliefs about teaching and learning, and their way of expressing that changed during the project was primarily due to the case-based nature of the project instead of the collaborative aspect of the project. In other words, the same results could have achieved without the use of the technology as a medium for collaboration.

3.2. Goal Two: Provide the Participants a Collaborative and Constructivist Learning Experience

Apparently this goal was only half successful. As pointed out in the previous section, the collaborative aspect of the project was not very successful. While the project took the form of collaboration, it was more of an individual process. However, the project provided the participants an opportunity to experience Constructivist learning. In this project, the participants were guided through a typical constructivist process of learning. First, the tasks in the project were authentic in that it acknowledged learners' ownership of learning; it was project-based; and it fostered multiple perspectives [1]. Second, it started from the learner's prior experience and existent knowledge. Third, it encouraged the participants to construct knowledge instead of memorizing information.

Why the lack of collaboration?

The failure of the collaboration aspect of the project resulted from a combination of several factors: some organizational, some technical, and some epistemological.

The belief in authority or trying to be "correct" prohibited collaboration.

When asked to comment in their process journals about the reasons for such limited collaboration over the network in the first half of the project, many participants reported they were afraid that what they said might be wrong. Most of the participants had not been prepared to treat knowledge as an object that can be criticized, modified, compared, and regarded from different perspectives. Instead they subjectify knowledge, treating it as part of them. Therefore criticizing one's knowledge was considered equivalent to a value judgment about the person.

Unfamiliarity with the technology was another factor that negatively affected collaboration.

While we had expected that the using email would bring the convenience needed for frequent communication in this project, we completely underestimated the difficulties of using the technology. Although we provided training before and technical assistance during the project, in the first two months of the project, the participants experienced a tremendous amount of anxiety and frustration with email. Since this was the first time that many of the participants used email, they had little knowledge about how the system works. Thus when a problem occurred, they made the wrong interpretation and started to panic. For example, because at one time one participant's mailbox exceeded quota, everyone who sent a message to the list at that time received an error message from the mail server saying that the message "was not deliverable." While the error message explained clearly that the message was not deliverable to one person and that it was sent successfully to everyone else, most participants interpreted it as the message had not been sent to anyone. So they started to either blame themselves for not being skillful or the computer for being so "stupid." One participant sent out five self introductions, while blaming himself for not being smart enough to know what to do. But his messages were successfully received by the list.

"Not sure about the email thing" was also one of the most often cited reasons for the lack of collaboration in the participants' process journals. Over half of the participants made statements similar to the following:

> *I really think that a lot of people are still "computer phobic". In speaking from experience, I can honestly say that I felt overwhelmed with all of this e-mail stuff that we had to do.*

Collaborating electronically also meant for some people a change in their way of composing. Some participants were not yet used to composing directly on a computer. They first wrote on paper and then typed into a computer. This might have influenced the project as well.

The large group was another factor that inhibited students from collaborating.

One mistake we made in terms of design was beginning the project by putting all students in a group of over sixty people from two different institutions. Initially we made that decision based on two considerations. First, most professional listserv groups have many more members than 60. Since one of our goals was to introduce the participants to the utilization of technology in education, we thought it would be a good way to help them develop the skills to cope with large number of email messages, a situation likely to be encountered when subscribing to any of the thousands of professional mailing lists. Second, we thought having a large group would produce more diversity of ideas and thus evoke better discussions. Evidently our assumptions were wrong.

After we put the participants in smaller groups, there was much more discussion and collaboration.

Students reported that they felt much more comfortable posting ideas and critiquing others when they "know the names of the group."

To summarize, even though the project failed to provide the participants the opportunity of a collaborative learning experience, they did witness how a collaborative project could be organized and then adjusted when it did not work. They also experienced, as expected, constructivist learning.

3.3. Goal Three: Help the Participants Develop Skills With Technology and Goal Four: Help the Participants Develop a Positive Attitude Toward Medium-Mediated Communication.

These two goals are closely related. We found that the more skillful the participants became with the technology they more positive they felt about email communication. These two goals are thus discussed together.

In general, these two goals were achieved. As a result of this project, all participants can use email for communication. Although proficiency may vary from individual to individual, all participants have acquired at least the basic knowledge and skills to use one or another application program to send and receive electronic mail. Toward the end of the project, the number of messages exchanged over the network increased dramatically. While this increase resulted from a combination of factors, familiarity with technology was certainly among the primary ones.

Another indication is that after the participants were put into small groups, they had to create their subgroup list, a non-trivial task for beginners. Except for two, all did so successfully. When one group misspelled one instructor's email address, their messages were bounced back. Unlike earlier, not only did they not panic, but also successfully forwarded the message to the instructor without resending the messages to the whole group.

Participants unanimously reported in their process journals that one of the biggest achievements for them was that they learned "how to do email" or advanced their skills with the Internet. One student commented:

> *E-mail was very helpful. At first I hated the idea, and I don't know if I have gotten over my fear of not having a hard copy in hand of things, but I sure don't have a fear of using e-mail anymore. I learned how to keep my mailbox clean. I learned how to use pine. And now I know how to send documents through pine.*

A reason to use technology is perhaps the most important factor contributing to improved skill.

A recent report by the Office of Technology Assessment [5] on Teacher and Technology suggest that teachers need more knowledge about technology in order to make use of it in their classrooms, but a problem remains in how to deliver that knowledge. This project provides at least one alternative. Instead of teaching technology, we gave the students a reason to use it. To use it was to learn it.

This, however, does not mean that they can learn automatically or easily. During this project we provided training at the beginning and on-going support during the project. We did not attempt to teach them everything at once, rather we provided resources whenever they needed in a supportive atmosphere.

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