

Scaffolding Group Learning in a Collaborative Networked Environment

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ABSTRACT

Scaffolding students in a collaborative networked learning environment requires different instructional methods than in a traditional home or classroom setting. The goal of this research is to understand computer-mediated collaboration in an instructional setting in order to create an effective computer-mediated collaboration tool. We identify ways to support collaboration by examining the interaction and strategies employed by a peer tutor and teacher and between peers working in our collaborative learning environment. We found that supporting collaboration in an electronic setting requires diagnosing impasses, facilitating problem-solving interaction, and suggesting ways to divide the problem into sub-tasks.

Keywords

computer-mediated collaboration, tutoring, learning environments

INTRODUCTION

Proponents of collaborative learning claim that students in cooperative teams achieve higher levels of thought and retain information longer than students who work quietly as individuals (Webb, 1995). Students learning effectively in groups encourage each other to ask questions, articulate their thoughts, explain and justify their opinions, and elaborate and reflect upon their knowledge. Yet, the field of CSCL (Computer-Supported Collaborative Learning) continues to struggle to identify how best to support collaborative learning online as new communication technologies allow the learner to network with other learners (Berge, 1997) and as CSCL becomes an established research paradigm for electronic learning environments (Koschmann, 1996).

How does a collaborative networked learning environment impact the types of tutoring needed to effectively scaffold students? We report on a study that compares peer-mediated instruction and teacher-mediated instruction to inform scaffolding in a collaborative networked learning environment. The goal of this research is to investigate how peers and teachers support group learning in a networked environment so in the future, we can use this model to inform the design of electronic scaffolds for our learning environment.

THEORETICAL RATIONALE

The following sections provide a foundation and rationale for our work. A brief discussion of collaborative learning and technology-based learning environments will establish a framework for our study.

Collaborative Learning

Many educators and learning researchers have found promise in Vygotsky's (1978) social constructivist ideas about learning in a social setting. His notion of the zone of proximal development (ZPD) posits that children's mental development can be positively influenced by the assistance of an adult or more capable peer. The core concept of constructivism is that understanding and knowledge come from our interactions with the environment (Savery & Duffy, 1996). Studies suggest that communicating ideas in a group setting encourages self-explanation and justification, both of significant instructional value (Rogoff, 1990; Webb, 1991).

Different groupings of learners with or without tutors have been shown to be effective in improving student achievement. Bloom (1984) demonstrated that tutoring raises students' performance by .40 standard deviations with peer tutors and 2.0 standard deviations with experienced tutors. What strategies do experienced tutors use to facilitate learning? Graesser, Person and Magliano (1995) documented the techniques used by to facilitate problem-solving: *pumping* to expose student knowledge; *prompting* to supply the student with context to fill in missing information; and *splicing* to provide the student with correct information when they make a mistake. Other tutoring strategies found by Graesser et. al. include hinting, summarizing, elaborating, assessing, and providing feedback.

Research on peer interaction suggests that peers can mediate each other's learning. McCarthey and McMahon (1992) found that in a peer-tutoring situation, the discourse tends to be unidirectional, from the more knowledgeable student to the less knowledgeable student. Unfortunately, peers may not collaborate effectively. Nelson-LeGall (1992) suggests that with schooling, students perceive that competition and independent performance are increasingly normative, which may account for their failure to seek help from their peers and even from their teachers.

How does working with a peer compare to working with a teacher? In comparing the effectiveness of working with experts or peers, Salomon and Perkins (1998) note an interesting difference between expert tutoring and peer problem solving. Whereas tutors aim to facilitate the learning of the student(s), peers working together often aim just to accomplish the task. As a result, the individual learner often gets more of a chance to participate actively in the problem-solving effort when interacting with an expert tutor than with same-level peers. In fact, students working in groups appear to be more focused on finding the right answer than in mediating each other's learning (Vedder, 1985). Therefore, in many cases, an expert tutor may be needed to support peer problem-solving. Why scaffold collaborative learning? Despite studies (e.g. Webb, 1991) showing that social learning situations correlate with a wide range of positive outcomes – such as improved learning, increased productivity, and higher motivation – collaborative learning does not work for all learners. According to Brown and Palincsar (1989), “social interactions do not always create new learning; peer interactions vary enormously.” (p. 397). Several researchers (King, 1994; Webb, 1995) have found that it is the nature of peer interaction that is perhaps the most critical factor mediating individual student achievement.

The human tutoring literature shows that expert tutors can effectively support students, and that peers can mediate each other's learning. However, these studies of tutoring are based on individual tutoring situations or face-to-face group instruction, which may not necessarily apply to networked learning. The next section explores technology-based learning environments that can support collaborative learning.

Computer Support for Collaborative Learning

Technology has taken on new roles in learning, providing students with the opportunity to interact with responsive, dynamic environments that support learning. These computer-based interactive learning environments have traditionally been designed to support a single student's needs. Interactive learning environments (ILEs) are commonly grounded in constructivist theories on learning, which emphasize that knowledge is something that a student constructs based on his or her prior knowledge and experience. ILEs are designed for a single student but may have a computer tutor to assist in learning. Computer tutors in interactive learning environments, also known as Intelligent Tutoring Systems (ITS), can diagnose the conceptual difficulties and misunderstandings of any student. Brown and VanLehn (1988) found that learning occurs when students encounter problems, at which point they need help to repair their incorrect procedures. The tutor, then, is able to intervene at those salient points.

CSCL environments, in addition to supporting learning of subject matter, also support students working together at a distance or at the same computer. These systems have the potential to enhance the effectiveness of peer interactions, by coaching peers as they work on problems and critique other students' solutions. A human or computer tutor can help structure the interaction, give advice when needed, and promote deepening of understanding. From studies of an ITS called Sherlock (Lajoie & Lesgold, 1989), Katz and Lesgold (1993) believe that the tutor has three main roles to play in collaborative learning situations: (1) provide advice on demand, (2) provide quality control over collaborative activities, and (3) manage peer collaboration. Our study also investigates the role of a tutor in a computer-support collaborative learning environment, but we conduct an empirical study with human tutors to answer this question.

Our study is designed to understand the effective strategies of human tutors in a CSCL environment, in which networked computers link the participants. What is the nature of peer and expert tutoring? How does such an environment impact the types of tutoring needed to effectively scaffold students? The goal of our research is to determine how best to support learning in a CSCL environment. Our long-term goal is to use the results of this study to inform our design of electronic scaffolds for a group of students working together on tasks requiring conceptual understanding.

METHOD

We conducted a small study that examined the role of a teacher or more experienced peer with one or two other students in a challenging problem-solving situation. We chose algebra as our subject domain because algebra provides concrete, well-defined problems on which students can collaborate. Our existing system, ALGEBRA JAM (Singley, Fairweather & Swerling, 1999), supported collaborative problem-solving and was an appropriate environment for exploring various collaborative arrangements.

Collaboration in ALGEBRA JAM

ALGEBRA JAM is a collaborative learning environment that supports teams of students as they collaborate synchronously and remotely to solve situated, multi-step problems involving algebraic modeling. Students are provided with resources containing information they need to solve an algebra word problem and given various tools to support collaboration.

The blackboard, shown in the top right of Figure 1, supports the participants as they share ideas about how to attack a problem, and monitor team progress. They can post the variables they need to compute as nodes in the goal tree. Any changes in the blackboard are reflected synchronously to other participants in the session; the students cannot make their work private. To aid in collaboration, a face of the user(s) with whom a student is collaborating is displayed in a panel to the right of the blackboard.

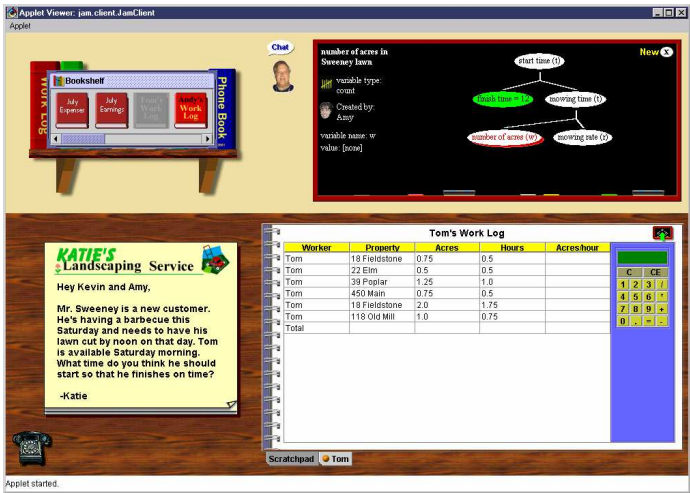


Figure 1 : ALGEBRA JAM interface

The tabbed workspace, shown in the lower right of Figure 1, is an area where students work with the various information resources required to solve the problem. The resources are dragged from the bookshelf in the upper left corner of Figure 1. Like the blackboard, when one participant performs an action in the tabbed workspace area, that action is reflected synchronously to all other participants. This is intended to encourage collaboration in that students can work together to write equations, perform calculations, model solutions, and evaluate each other’s work.

Rather than provide a generic chat facility, ALGEBRA JAM allows learners to participate in threaded discussions tied spatially to the work products and interface objects with which they were working. Learners communicate with one another by typing a message while pointing to a particular object on the screen. Users can place a chat balloon anywhere on the screen to focus their conversation or chat about a particular action or object. To further support collaboration, users must identify the type of comment they are contributing. The goal is to encourage metacognition in students.

Participants

The participants were eighteen 8th-12th graders from summer school programs in the metropolitan New York area. The students who participated in the same groups knew each other. The teacher was a high-school math teacher with 22 years of teaching experience. The peer tutor was a student who also participated in our study as a (non-tutor) student and agreed to return in the role of a tutor in subsequent experiences.

Design of Study

We placed participants in one of four experimental groups as arranged in Figure 2. We observed three sets of participants in each condition.

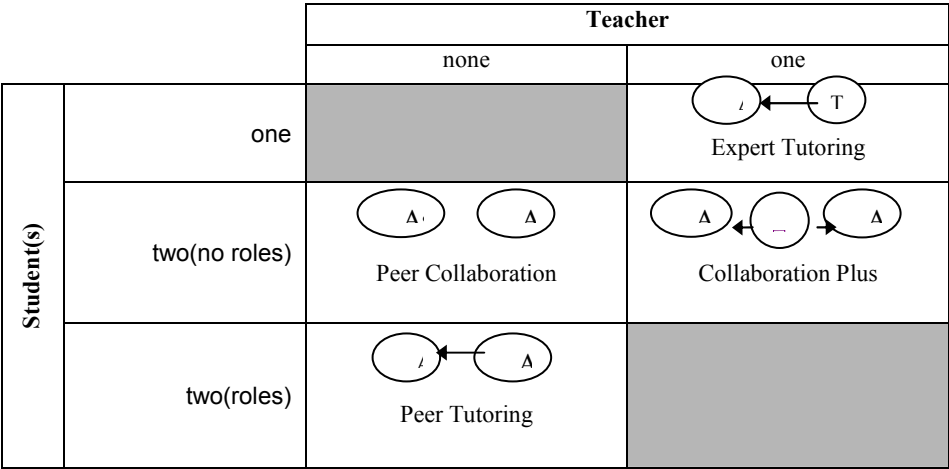


Figure 2: Experimental Groups

The “Expert Tutoring” condition involved one student working with one teacher. We expected that students in this condition would regularly consult the teacher for advice and suggestions. The “Peer Collaboration” condition involved two students working together without role assignment (i.e. neither student was told to tutor the other). We expected that when two students were present, they would work closely, collaborating on most decisions, since they were provided tools to support collaboration and a design that encouraged working together. “Collaboration Plus” involved two students working with a teacher. We hypothesized that students would approach the teacher more than they would consult one another for help. “Peer Tutoring” involved two students working together, in which one played the role of a tutor. The peer tutor had been given instruction on the problems before assuming the tutor role. We suspected that the peer tutor would be approached in a manner similar to how the teacher was approached.

Procedure

Prior to using the system, the participants were instructed on its features as we demonstrated a scenario between two users. The students working together were not directed on how or when to collaborate and were merely told that they would be working together using computers in different rooms. The students in the same groups knew each other previously. In the “Expert Tutoring” and “Collaboration Plus” conditions, the teacher was introduced as a resource if the student(s) encountered difficulties. The teacher was not provided direction on how frequently to provide assistance to the student(s). The teacher, placed in a separate room than each student, could see the events that each of the students saw on their computer. Each group of participants was given a set of three problems to solve in one hour using the system. Each problem involved a landscaping scenario in which students had to solve for variables such as mowing rate or the time to complete a job. The same resources were available on the bookshelf throughout the session.

Analysis

No measures were taken to assess learning because of the short timeframe in which the participants used the system and the design of the open-ended algebra problems. We focused on the nature of the collaboration and did not assess cognitive gains. From the transcripts of the chats, we analyzed the manner in which the human tutors offered assistance and responded to student successes and struggles. We also coded the participants’ actions and decisions so we could identify general strategies and techniques employed by peer tutors and teachers when students encountered difficulties. We identified types of feedback offered by a tutor and calculated the number of times a tutor mediated the problem-solving effort.

FINDINGS

We present our findings at two levels. First, we examine the collaboration, or the flow of information, that occurred between participants in ALGEBRA JAM. We begin by looking at how often learning is mediated and by whom. Then, we discuss *how* the participants mediated each other’s learning.

Modeling information flow

Information flow is defined as the sharing of meaningful, relevant information that assists in completing the task. We have modeled the information flow between participants in each condition to summarize our findings in Figure 3. The data to

support these diagrams is discussed in the following sections. We had expected to see arrows between the two students in the collaboration conditions, but no useful information was exchanged between peers.

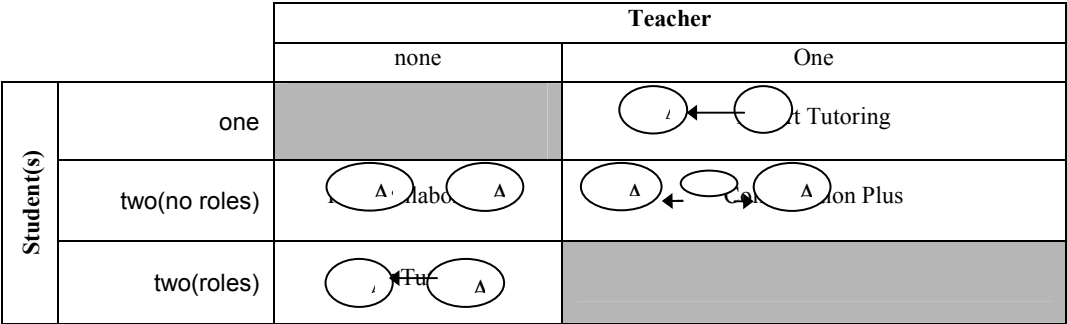


Figure 3: Observed information flow

In the “Tutor mediation” tables in this section (Tables 1, 2, and 3), we list the number of problems which the student(s) attempted, the total number of times the teacher intervened during the session, the percentage of interventions solicited by the student, and the percentage of interventions initiated by the teacher during that session. “Peer Collaboration” does not have a table since no tutor participated in that condition.

Expert Tutoring

In “Expert Tutoring”, the students regularly consulted the teacher for advice and suggestions. Most of the information was flowing from the teacher to the student, as illustrated in Passage 1.

Tutor: Good, now how many more minutes is the first time besides 120?
 Timmy: So is it 120.15?
 Tutor: 120 minutes + 15 minutes =
 Timmy: 135

Passage 1: Information directed from teacher to student

In the “Expert Tutoring” condition, most of the interaction involved the problem-solving process. On average, the student solicited approximately 45% of the teacher interventions in this condition; 55% were initiated by the teacher. Only one of the three students progressed past the first problem. Table 2 shows that his session was the only one in which the percentage of solicited interventions was greater than the percentage of tutor-initiated interventions.

Expert Tutoring	Problems Attempted	Tutor Interactions	Student-Solicited Interactions n(%)	Tutor-Initiated Interactions n(%)
Group 1	1	13	6(46.1)	7(53.8)
Group 2	2	9	5(55.5)	4(44.4)
Group 3	1	9	3(33.3)	6(66.7)
Average	1.3	10.3	4.7(45.0)	5.7(55.0)

Table 1: Tutor mediation for “Expert Tutoring”

Peer Collaboration

In “Peer Collaboration”, where neither student was more knowledgeable than the other, the pair worked independently even when collaboration would have been more efficient. Students would do their own work, as evidenced by Passage 2 from our chat transcripts. We also saw in this condition the students were extremely off task.

Thomas: Did you do the problem?
 Nick: I'll call you back in a minute
 Thomas: Did you finish?
 Nick: I'm going to try to finish the last problem...

Passage 2: Lack of peer mediation

Collaboration Plus

In “Collaboration Plus”, where a teacher and a same-level peer are present for consultation, we found that neither the teacher nor the peer were asked directly for help. The teacher decides when to intervene to guide or redirect the students. The students did not share useful information, although they did interact more with a teacher present than they did in the “Peer Collaboration” condition without a teacher. They usually only interacted to encourage each other or put each other down, as in Passage 3.

Tutor: You have total acres and total hours. How do you get the rate?
Aaron: Ohhhhh my bad.
Brandon: Yes it is your bad.
Aaron: Shut up. I didn't hear you come up with some answer, Mr. I-know-it-all.

Passage 3: Peer interaction in “Collaboration Plus”

Sometimes, students would lead each other down the wrong path and the teacher would intervene. With multiple students, the teacher, instead of being solicited by the learner(s) as in “Expert Tutoring”, initiates more of the mediation. Table 2 shows that a large percentage (90% average) of the tutor mediation in “Collaboration Plus” was tutor-initiated, compared to Table 2 in “Expert Tutoring” which showed tutor-initiated interactions averaging 55%.

Collaboration Plus	Problems Attempted	Tutor Interactions	Student-Solicited Interactions <i>n</i> (%)	Tutor-Initiated Interactions <i>n</i> (%)
Group 1	1	17	1(5.9)	16(94.1)
Group 2	3	10	1(10.0)	9(90.0)
Group 3	1	15	2(13.3)	13(86.7)
Average	1.3	14.0	1.3(9.7)	12.7(90.3)

Table 2: Tutor mediation for “Collaboration Plus”

Peer Tutoring

In “Peer Tutoring”, the peer tutor was consulted in a similar fashion to the teacher in “Expert Tutoring”. No fewer questions were asked than in the condition where a teacher was present. The peer tutor seemed to be an adequate substitute for the teacher in terms of answering questions and directing students. The following transcript passage, Passage 4, is an example of effective guidance by a peer-tutor.

Peer Tutor: No...what are u trying to find in the “Phillip” book?
Tremaine: The amount of acres that he mows per hour
Peer Tutor: Yes...his average rate of lawn mowing. How does one find an average?
Tremaine: Divide

Passage 4:Effective peer tutoring

Information was directed from the tutor to the student, just as we saw in the “Expert Tutoring” condition. As shown in Table 3, our data set demonstrates that a peer, with a lower average number of interactions, intervenes slightly less than a teacher. The average number of interactions between the teacher and the student was 10.3 in the Expert Tutoring condition (as shown in Table 2), as opposed to an average of 8.7 interactions in this condition.

Peer Tutoring	Problems Attempted	Tutor Interactions	Student-Solicited Interactions <i>n</i> (%)	Tutor-Initiated Interactions <i>n</i> (%)
Group 1	1	9	5(55.6)	4(44.4)
Group 2	2	7	2(28.6)	5(71.4)
Group 3	1	10	1(10.0)	9(90.0)
Average	1.7	8.7	2.7(31.4)	6.0(68.6)

Table 3: Tutor mediation for “Peer Tutoring”

Summary of Information Flow Findings

From studying the flow of information between participants, we found that when a teacher or peer tutor is present, information is directed from the tutor to the student. In contrast, in “Peer Collaboration” where another same-level peer was available for help, students did not exchange useful information with each other to mediate the learning process; the teacher initiated almost all the interaction in that condition. When two peers are working together with or without the presence of a tutor, the peers work independently and do not mediate each other’s learning.

Instructional Strategies

We coded the types of strategies used by tutors, and we found five categories that are derived from Graesser and his colleagues’ (1995) categories. We did not code the “Pure Collaboration” condition because we did not observe information flow between the students in those groups. The types of mediation we coded were *leading*, *prompting*, *hinting*, *probing*, and *diagnosing*. Figure 4 categorizes the percentage of interventions by both a teacher and a peer-tutor according to the instructional strategies they employed.

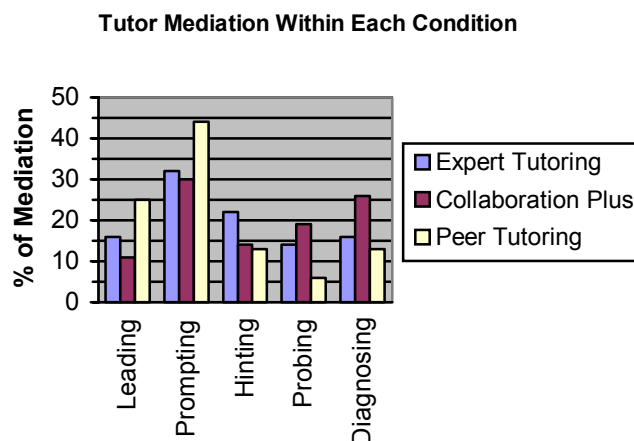


Figure 4: Instructional strategies graph

Leading

Leading differs from *prompting* in that in a leading strategy, the tutor is specifically directing a student to complete a task. Leading would mean answering a question such that it solves part of the problem, as illustrated in Passage 5. Peer tutors did almost twice as much leading as did teachers. A teacher used similar strategies whether working with one student or two simultaneously.

Timmy: I don't know how to figure that out

Tutor: The last column is acres divided by hour. That would be how much work Phillip did in 1 hour.

Passage 5: Example of *leading* by a teacher

Prompting

In *prompting*, tutors (either a peer or teacher) ask questions so that the student can arrive at the answer himself or herself. In Passage 6, the teacher is prompting the student to a particular answer. *Prompting* is the strategy that the teacher and peer tutor used most often when mediating learning.

Tutor: Where would we find the information we need?

Timmy: Phillip's timesheet

Tutor: Good, now what does this tell us?

Timmy: How many hours Phil worked

Tutor: Ok, and what else?

Passage 6: Example of *prompting*

Hinting

Hinting differs from *prompting* in that hints usually take the form of analogies or reminders and may not relate specifically to the problem. Passage 7 illustrates hinting. The teacher employed the hinting strategy more often than did the peer tutor.

Tutor: Remember what rate is?

Timmy: Is it the consistency of something?

Tutor: Heart rate we defined as the amount of work that your heart does in a given time.

Tutor: So Phillip's rate would be _____?

Passage 7: Example of *hinting*

Probing

Probing involves the tutor asking questions to make sure a student understands the problem, as in Passage 8. A peer tutor seems to do less *probing* than a teacher to make sure an idea or concept is understood.

Tutor: You already did his total acres so we just need the total time.

Timmy: 19.669 acres in 19.669 total time

Tutor: How did you get 19.669 for total time?

Passage 8: Example of *probing*

Diagnosing

Diagnosing is a strategy in which tutors provide feedback by evaluating the student's ideas and actions in the learning environment. As illustrated in Passage 9, *diagnosing* provides the student with immediate input about their progress. In our study, a teacher did more *diagnosing* than a peer tutor.

Tutor: You are correct – John has mowed 15.75 acres before.

Tutor: You are also right that there are 60 minutes in an hour.

Passage 9: Example of *diagnosing*

Summary

Primarily, human tutors in a learning environment take the learner through the problem by asking questions pertaining to the problem at hand. The teacher did less *probing* and *diagnosing* and more *leading* and *hinting* in the “Expert Tutoring” condition than in the “Collaboration Plus” condition. It also appears that a peer tutor prefers *prompting* followed by *leading* to mediate student learning. Overall, we found that the notion that a problem-solving partner is more knowledgeable, regardless of his or her status or teaching experience, seems to provide a student with more inclination to ask questions of the partner than in the case where the partner is a same-level student.

DISCUSSION

We had hypothesized that students in the “Expert Tutoring” condition would consult the teacher regularly for advice and suggestions. We saw in Table 2 that a student initiated more of the interaction in the case when he or she was able to solve a problem, whereas the teacher initiated more of the interaction when the student was struggling. This would be a logical result of students not knowing when to ask for assistance or what types of questions to ask. In responding to the student, we found that the teacher used *prompting* most frequently, followed by *hinting*. It seemed that the teacher expected the students to find the answers on their own with some direction.

We had hypothesized that students would work as equals in the “Peer Collaboration” condition, working together since they were information resources for each other in the environment. But the students had no prior training in how to collaborate and were not given explicit instructions on how to work together. Perhaps as a result, they proceeded as individual problem-solvers; there was no shared knowledge. Even though the participants in this condition were not complete strangers, they needed support in working together.

We had expected in the “Collaboration Plus” condition that we would see the teacher being consulted more often than the other student. However, in most cases, questions or remarks would not be addressed to either participant, and the teacher would be responsible for initiating the interaction. In “Collaboration Plus,” the instructional strategies used by the teacher were primarily *prompting*, followed closely by *diagnosing*. We also noticed that the teacher aimed to facilitate the learning of the student, whereas the peer often aimed just to find the right answer. Furthermore, when students did interact, they often misdirected each other or moved off-task, requiring teacher intervention. This is more evidence that the collaboration process needs to be scaffolded in a networked environment.

Lastly, we believed that a peer tutor would be approached online by a student in a similar manner to a teacher. We found that the tutor initiated interaction more often than the student asked for assistance. Because of the nature of the task and the differences in expertise, the tutor assumes more of a traditional teacher role and thus dominates the dialogue. Unlike when the teacher was acting as the tutor, we found that the peer tutor almost half the time chose the more straightforward, simple instructional method of *prompting*, followed a quarter of the time by *leading*, another less sophisticated approach, to help a student.

IMPLICATIONS AND CONCLUSION

We conclude by returning to our research questions. How does a CSCL learning environment impact the types of support needed to effectively scaffold students? Which elements of peer interaction and teacher interaction are effective in supporting collaborative learning? We cannot make strong claims due to the size of our study, but our results suggest interesting areas for further exploration.

Design Implications

We noted general design implications from tutor-mediated instruction for designing support for groups of students working in electronic learning environments. In “Expert Tutoring,” we saw that the teacher initiated more of the interaction when the student was struggling. Support for group learning should diagnose student progress and intervene at impasses. This is consistent with the findings of Brown and VanLehn (1988) described earlier. A human or computer tutor does not necessarily need to provide immediate feedback, but a model tracing student progress could ensure that students do not get too far off track.

Scaffolds in CSCL environments should also improve communication between students to accelerate their path along an acceptable solution trajectory. We saw in the "Peer Collaboration" condition that students proceeded as individual problem solvers with little useful information shared between them. As suggested earlier in this paper, discussing and explaining ideas to peers is a useful learning strategy. This suggests that supporting collaboration requires (1) diagnosing impasses to redirect incorrect solution paths, (2) facilitating problem-solving interaction to keep students engaged, and (3) suggesting ways to divide the problem into sub-tasks for which each participant can be responsible. These functions are somewhat similar to the findings by Katz and Lesgold (1993) of the role of the tutor in a collaborative situation, except that our results suggest that the tutor in a CSCL environment needs to be more pro-active in providing advice. Rather than leaving to students the responsibility for deciding when advice is needed, we believe the tutor needs to identify problems and provide redirection.

Finding the optimal balance of peer and expert tutoring strategies is an important research challenge. There are times when a knowledgeable expert is needed, and other times when a peer, to which ideas can be explained and justified, is appropriate. Our study suggests, however, that peers need to be instructed on how to collaborate before they can be effective at facilitating each other's learning. Experts also need to give students the chance to work together and correct each other before jumping in with the solution.

Conclusion

More research needs to be done to examine how traditional methods of tutoring differ when the participants are interacting over a computer. More studies should also explore how students learn differently with peers versus teachers in an electronic environment. This study demonstrated that the techniques used to scaffold learning in a CSCL environment are different from interactive learning environments. Not only does individual learning need to be supported, but the interaction between participants needs to be facilitated because outside of the social context of the classroom, it is easy for the students to become disengaged.

We have performed a small study that has looked more generally at the role of peers, a knowledgeable peer-tutor and a teacher put into an electronic tutoring situation. Our findings suggest that there are significant advantages for both knowledge-rich interactions and peer-to-peer collaboration. Designers of collaborative learning environments need to capture these advantages by developing scaffolds that can effectively lead, prompt, hint, probe, and diagnose in a way that supports team problem-solving without actively leading the team towards a predetermined outcome.

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