F. (PEDAGOGY TRACK): COMPUTER SUPPORT FOR PROBLEM-BASED LEARNING

Collaborative Ways of Knowing: Issues in Facilitation

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ABSTRACT

This paper describes a detailed analysis of a student-centered problem-based learning group. The focus of this analysis is to understand the goals and strategies of an expert facilitator. This was accomplished by examining the questions and statements that the students and facilitators generated and inferring the facilitator's goals and strategies. Studying facilitation in a face to face situation provides some guidance in designing support to use in an online problem-based learning environment; however, considerable adaptation is necessary as some facilitation can be built into the system but some facilitation may need to be done by a human tutor. Implications for CSCL system design for problem-based learning will be discussed.

Keywords

Problem-based learning, facilitation, student-centered learning

INTRODUCTION

One of the hallmarks of a constructivist classroom is its focus on student-centered discourse (Palincsar, 1998). In a typical teacher centered classroom, the teacher asks 95% of the questions; mostly requiring short answers (Graesser & Person, 1994). The typical mode of discourse is the IRE pattern in which the teacher initiates a question, generally aimed at getting a student to display their knowledge, the student responds, and the teacher evaluates that response. Thus the goal often focuses on having students learn facts. Teacher's strategies are influenced by their goals for teaching and beliefs about learning (Schoenfeld, 1998). In contrast, inquiry teachers have goals that include having students learn the facts but their goals go to higher levels as well. A study of inquiry teachers identified several different types of goals and strategies that are used (Collins & Stevens, 1982). They found that inquiry teachers' goals include having students learn theories and how the theories are derived. Inquiry teachers believe that it is important for students to be active agents in knowledge construction. This includes having students learn what questions to ask, how to make predictions from theories, and how theories and rules can be tested. Their analyses indicate that these teachers use different kinds of strategies to achieve these goals. For example, they may select appropriate cases and counterexamples to encourage the students to generate hypotheses, make predictions, reveal their misconceptions, and test their ideas. In inquiry teaching, the students are more active than in IRE discourse but the teacher still leads the discussion, working towards global learning goals but choosing strategies on the fly.

Social constructivist approaches to learning are said to be student-centered, with students driving the discussion and the teacher serving as the guide on the side (Palincsar, 1998). Determining exactly what that means and how student-centered learning can be facilitated are important in being able to implement constructivist approaches more broadly. One way to examine this is to analyze the goals, strategies, and tactics of a master facilitator. Understanding how an expert facilitates in terms of the goals, strategies, and tactics that he uses has important implications for training new facilitators and in designing CSCL systems. Examining group discourse in terms of who is asking questions, the nature of the questions asked, and the nature of the responses can provide some insight into characteristics of a student-centered classroom. This paper reports on a study of a specific student-centered learning environment, problem-based learning (PBL). PBL is widely used in medical schools (Barrows, 1988; Schmidt et al, 1996). PBL is an example of a cognitive apprenticeship (Collins, Brown, & Newman, 1989). In a cognitive apprenticeship, students learn in the context of solving complex, meaningful tasks. The role of the teacher is to make key aspects of expertise visible and making tacit thinking processes explicit. In PBL, students learn through solving problems and reflecting on their experience. They work in small groups guided by a facilitator. The role of the facilitator is guiding students on the learning process, pushing them to think deeply, and modeling the kinds of questions that students need to be asking themselves. The collaborative groups provide a forum for students to distribute the cognitive load and negotiate shared understanding as they solve the problem. This study analyzes the group discourse during two PBL sessions to better understand the learning process. It focuses on the interaction between a master PBL facilitator and an experienced group of PBL students.[1]

A PBL tutorial session begins by presenting a group, typically 5-7 students with a small amount of information about a complex problem (Barrows, 1988; Hmelo & Ferrari, 1997). From the outset, students question the facilitator to obtain additional information; they may also gather facts by doing experiments or other research. At several points, students pause to reflect on the data they have collected so far, generate questions about that data, and ideas about solutions. Students identify concepts they need to learn more about to solve the problem (i.e., learning issues). After considering the case with their existing knowledge, students divide up and independently research the learning issues they identified. They then regroup to share what they learned, and reconsider their ideas in light of what they have learned. When completing the task, they reflect on the problem to abstract the lessons learned, as well as how they performed in their self-directed learning and collaborative problem solving. This helps prepare the students for transfer (Salomon, Perkins, & Globerson, 1989).

While working, students use whiteboards to help scaffold their problem solving. The whiteboard is divided into four columns to help them record where they have been and where they are going. The columns help remind the learners of the problem-solving process. The whiteboard serve as a focus for group deliberations. The *Facts* column holds information that the students obtained from the problem statement. The *Ideas* column serves to keep track of their evolving hypotheses. The students place their questions for further study into the *Learning Issues* column. They use the *Action Plan* column to keep track of plans for resolving the problem.

METHODS

Data Sources

The participants in this study were five second-year medical students, who were experienced in PBL, and a master facilitator. Students worked on a problem for five hours over two sessions. The sessions were videotaped and transcribed. In addition, the researcher reviewed the audiotapes with the facilitator and interviewed him regarding his goals and strategies for particular discourse moves.

Coding and Analysis

The entire transcript was coded for the types of questions and statements in the discourse. All the questions asked were identified. They were coded using Graesser and Person's (1994) taxonomy of question types as well as several additional categories that were developed to capture monitoring, clarification, and group dynamics questioning (see Table 1). Three major categories of questions were coded. Short answer questions required simple answers of five types: verification, disjunction, concept completion, feature specification, and quantification. Long answer questions required more elaborated relational responses of nine types: definitions, examples, comparisons, interpretations, causal antecedent, causal consequences, expectational, judgmental, and enablement. The meta category referred to group dynamics, monitoring, self-directed learning, clarification-seeking questions, and requests for action. Any questions that did not fit into these categories were classified as uncodeable.

Statements were coded as to whether they were new ideas, modifications of ideas, agreements, disagreements, or metacognitive statements. Each of these statements was coded as to its depth. Statements were coded as simple if they were assertions without any justification or elaboration. These corresponded to responses to the short answer questions. These included verifications, concept completions, and quantities. Elaborated statements went beyond simple assertions by including definitions, examples, comparisons, judgments, and predictions. These would be responses to long answer question types 7-10, 14, and 15 in Table 1. Statements were coded as causal if they described the processes that lead to a particular state or resulted from a particular event (i.e., responses to question types 11-13). Statements were also coded as to whether they were read from the case information, repetitions of a previous statement, or uncodeable statements. An independent rater coded ten percent of the discourse; interrater agreement of greater than 90% was achieved.

RESULTS

Questions and Statements

Students were expected to ask a substantial number of questions. The meta questions were expected to be the major category for the facilitator. The distribution of questions is shown in Figure 1. Because these were experienced PBL students, they were also expected to generate a substantial number of this type of question. A total of 809 questions were asked, 466 by the students and 343 by the facilitator. The students asked 226 short answer questions, 51 long answer questions, and 189 meta questions. Of the short answer questions, the modal question type was to elicit the features of the patients' illness from the medical record, for example when Jim asked "Does it say anything about medications?"

[1] As in the PBL literature, the terms tutor and facilitator are used interchangeably in this paper.

Table 1. Categories of questions

Question Type	Description	Example
Short answer		
▪ Verification	Yes/no responses to factual questions.	Are headaches associated with high blood pressure?
▪ Disjunctive	Questions that require a simple decision between two alternatives	Is it all the toes? Or just the great toe?
▪ Concept completion	Filling in the blank or the details of a definition	What supplies the bottom of the feet? Where does that come from??
▪ Feature specification	Determines qualitative attributes of an object or situation	Could we get a general appearance and vital signs?
▪ Quantification	Determines quantitative attributes of an object or situation	How many lymphocytes does she have?
Long Answer		
▪ Definition.	Determine meaning of a concept	What do you guys know about pernicious anemia as a disease?
▪ Example:	Request for instance of a particular concept or event type	When have we seen this kind of patient before?
▪ Comparison	Identify similarities and differences between two or more objects	Are there any more proximal lesions that could cause this? I mean I know its bilateral.
▪ Interpretation	A description of what can be inferred from a pattern of data	You guys want to tell me what you saw in the peripheral smear?
▪ Causal antecedent	Asks for an explanation of what state or event causally led to the current state and why	What do you guys know about compression leading to numbness and tingling? How that happens?
▪ Causal consequence	Asks for an explanation of the consequences of an event of state	What happens when it's, when the, when the neuron's demyelinated?
▪ Enablement:	Asks for an explanation of the object, agent, or processes that allows some action to be performed.	How does uhm involvement of veins produce numbness in the foot?
▪ Expectational	Asks about expectations or predictions (including violation of expectations)	How much, how much better is her, are her neural signs expected to get?
▪ Judgmental:	Asks about value placed on an idea, advice, or plan	Should we put her to that trouble, do you feel, on the basis of what your thinking is?
Task oriented and meta		
▪ Group dynamics:	Lead to discussions of consensus or negotiation of how group should proceed	So Mary, do you know what they are talking about?
▪ Monitoring	Help check on progress, requests for planning	Um, so what did you want to do next?
▪ Self-directed learning	Relate to defining learning issues, who found what information;	So might that be a learning issue we can, we can take a look at?
▪ Need clarification	The speaker does not understand something and needs further explanation or confirmation of previous statement	Are you, are you, Jeff are you talking about micro vascular damage that then, which then causes the neuropathy?
▪ Request/ Directive	Request for action related to PBL process	Why don't you give, why don't you give Jeff a chance to get the board up.

The facilitator asked 39 short answer questions, 48 long answer questions and 256 meta questions. Short answer questions were often used to focus students' attention.

Long answer questions often asked the students to define what they had said or interpret information as for example when the facilitator asked a student "But I mean what produces the numbness at the bottom of the feet?" Meta questions were the dominant mode for the facilitator as he asked the students to evaluate one of their hypotheses "Well yeah, multiple sclerosis. How about that? How do you feel about that?…" These statements also included monitoring the group dynamics as he asked "So Mary, do you know what they are talking about?" The facilitator asked comparatively few content-focused questions. The distribution of question types differed for the facilitator and the students.

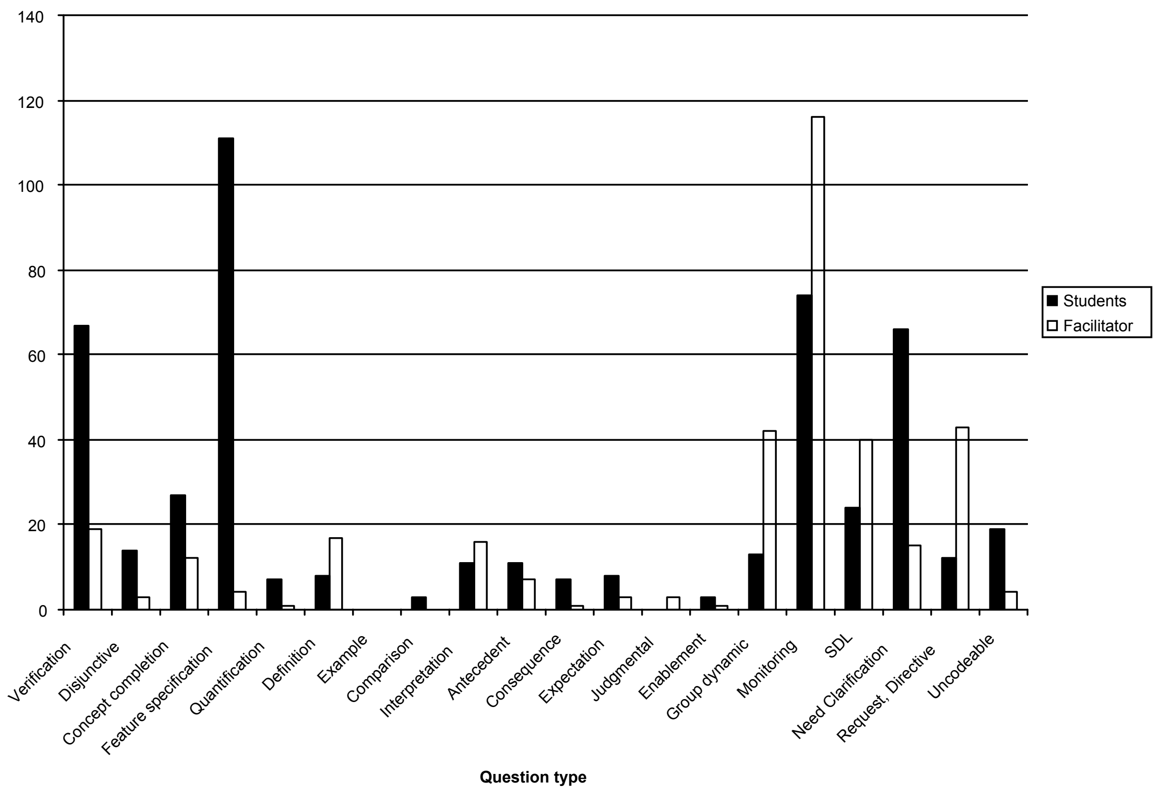

Figure 6. Distribution of question types

If the discussions were student-centered then it is reasonable to expect the students to do most of the talking. Moreover, if knowledge were being collaboratively constructed, the students' statements should be in response to previously introduced ideas. The facilitator should be offering few new ideas and making statements that are in the metacognitive category, centered around monitoring the groups progress in problem-solving and self-directed learning.

This was indeed the case. The facilitator made a total of 243 statements and the students made a total of 3763 statements. The distribution of statement types is shown in Figure 2. Clearly, the students are doing most of the talking. The distribution of statement types differed among the students and the facilitator. The facilitator made very few statements, rarely offering new ideas or modifying existing ideas. The facilitator was most likely to offer a comment monitoring the group's progress or encouraging students to consider that a poorly elaborated idea might become a learning issue. Both the metacognitive questioning and statements helped support the students collaborative knowledge construction as they build on the new ideas offered by others, expressing agreement, disagreement, and modifying the ideas being discussed. Of the first 4 categories of statements, the majority were simple statements (1641) but the students also made elaborated statements (464) and causal explanations (211).

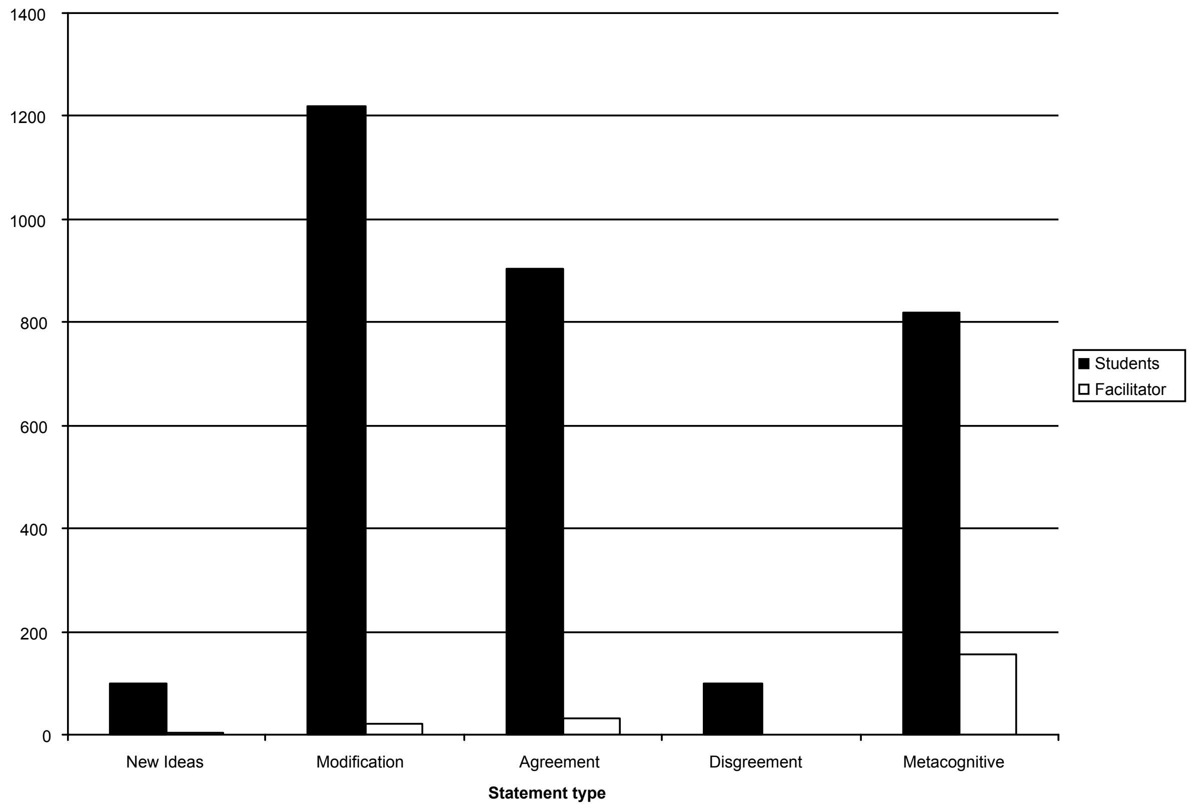

Figure 7. Distribution of statement types

While many of the statements taken individually were simple statements, taken as a collaborative explanation, they were elaborated, over several speakers and several conversational turns as occurred in this sequence after Barrows ask the students how the pernicious anemia hypothesis accounts for their concerns.

HB: Mary does that malnutrition vitamin B cover the, the things you were talking about just a minute ago? You were concerned about there's a number of different vitamins that may be involved.

MA: I hmmm.

HB: Can we just leave the, that hypothesis up?

MA: Oh yes. I think that's fine.

DE: Like pernicious anemia is a big one.

MA: Right. That must be the vitamin, the B.

HB: What, what's pernicious anemia?

DE: Uh, it's a deficient, deficiency of cobalamine.

MA: Vitamin B12, cobalamine or...

JM: Or folate.

MA: Or folate.

DE: Yeah, but it's not, that's not pernicious anemia. That's a, also another macrocytic anemia.

MA: Pernicious anemia is specifically.

JM: Oh. You're right. That's right.

DE: And um, you get anemia and you can also get eh, um, peripheral...

MA: Neuropathies.

DE: ... neuropathies.

HB: down there too?

CP: Technically pernicious, pernicious anemia is technically just the loss, the lack of intrinsic factor.

DE: The loss of intrinsic factor. So you don't absorb.

CP: And that's [unintelligible]

DE: You don't absorb.

CP: Right.

MA: Right. That's a good distinction. You see, we just...

CP: As opposed to like somebody who had part of their intestine removed and can't absorb.

MA: Right.

CP: But their ileum is gone and they can't absorb the B12. That's different than pernicious anemia.to vit, intrinsic factor.

This is collaborative because students all contributed different parts of the explanation. Barrows triggered the explanation but then different students offered different pieces of the explanation about pernicious anemia, what some signs might be (neuropathies) and what alternative explanations they can rule out (poor absorption of B12 in the gut). The students were themselves very metacognitive as they monitored their progress and understanding and considered their need for self-directed learning.

Goals and strategies

The fine-grained analysis provides useful descriptive information about the PBL tutorial. This is complemented by a qualitative analysis of the goals and strategies of the facilitator using a stimulated recall. The facilitator (Barrows) was interviewed on his goals and strategies while viewing the videotape. In addition, an interaction analysis session was conducted with a cognitive scientist to further elucidate the data interpretation.

The facilitator's overall goal emphasized that students needed to construct a causal explanation of how a disease leads to a particular pattern of signs and symptoms. He believed that students learned best through guided exploration of complex, ill-structured problem spaces. He focused on helping students become good reasoners as they looked for consistent mappings between different levels of explanations. Another important goal was helping the students become critical, self-directed learners who are cognizant of the limitations of their knowledge. His overall strategy was to use open-ended questioning and take advantage of the PBL routine.

One specific strategy that the facilitator frequently used was to push students for an explanation as he did in the example below when MA throws out the idea of multiple sclerosis as the cause of the patient's problem:

MA: Um, just given the idea that numbness in your feet, I had multiple sclerosis as a possibility. She is an older woman and multiple sclerosis, I believe, usually presents in the younger generation 30's and 40's, but it, it definitely can happen in an older person. So…

Facilitator: And tell us what multiple sclerosis is.

MA: Um, Multiple sclerosis is um, a progressive, it's a progressive and chronic debilitating disease um, where you get various points of sclerosis within the brain itself and it can affect different areas of um, of um, people's motor function. And it's called multiple sclerosis because there are multiple areas of these sclerotic plaques that occur in the brain.

Facilitator: What causes those plaques?

This serves the goal of placing the students' knowledge in public view and helping the students see the limitations of their understanding. Another strategy observed is that of revoicing (O'Connor & Micheals, 1993) in which the facilitator restates what a students has said.

MA: And another important um, hypothesis that's come is a vitamin B12 deficiency, which we've crossed out. Hah, because we didn't think she had any malnutrition. However, we found out that um, in the elderly there is a much, much higher prevalence of Vitamin B12 deficiency…

DE: And also I was just, happen to glance at it last night and um, 'cause I was just talking with my husband and, about the um, neurosyphilis and, and uh, the olivopontocereballer atrophy being pretty serious and progressive and, and I was thinking that vitamin B12 wasn't so much if you treated it. But it, I was reading that it's in a lot of the neur, uh, neural deficits are irreversible.

MA: Uh hmm.

DE: So it is, you know. It does put in my mind it's a more of a serious.

> Facilitator: Now you people are saying B12 all the time and yet when you say we eliminated it, you're talking about pernicious anemia, right?

The facilitator has accomplished three goals here. First, he has taken the idea put forth by the students and clarified it for the group as he restated it. Second, he has legitimated DE's idea. She is a quiet but extremely thoughtful student and she is recognized in this move. Third, he made sure this very important idea did not get lost. Pernicious anemia is the cause of the patients' problem and was in danger of being lost from the discussion. Table 2 provides a sample of some of the additional strategies that served as useful facilitation tools.

This study demonstrates that, in PBL, the students do a substantial amount of question-asking and explanation construction indicating that the tutorials are clearly student-centered. Moreover, the teacher's role is that of metacognitive guidance and scaffolding the collaboration. Specific types of questions are strategically used in the service of learning goals. These questions serve as scaffolds that are faded as students internalize the questions (Hmelo & Guzdial, 1996). These results suggest that through this cognitive apprenticeship, students see the big picture and integrate large bodies of learning and are becoming socialized into their community of practice through their learning discourse.

Table 2. A sampler of additional strategies

Strategy	Goals
Summarizing	Ensure joint representation of problem
	Establish common ground
	Help students synthesize data
	Move group along in process
Map between symptoms and hypothesis	Elaborate causal mechanism
Generate/ evaluate hypotheses	Help students focus their inquiry
	Examine fit between hypotheses and accumulating evidence
Check that students agree that whiteboard reflects their discussion	Make sure all ideas get recorded and important ideas are not lost
Cleaning up the board	Evaluate idea
	Maintain focus
	Keep process moving
Creating learning issues	Knowledge gaps as opportunities to learn
Encourage construction of visual representation	Construct integrated knowledge that ties mechanisms to effects

APPLYING THE LESSONS LEARNED TO ONLINE FACILITATION

The analysis of an expert facilitator has important implications for providing tools for facilitating online collaboration as well as providing a basis for training novice facilitators in PBL. These results provide suggestions for conversational moves that facilitators might make and representations that could embody the learning goals and strategies that an expert facilitator uses. There are other issues that this analysis does not address as well—for example, how does facilitation need to differ between synchronous and asynchronous environments.

The role of the facilitator in a face-to-face discussion has several aspects. First, the facilitator needs to help maintain the agenda and manage time. Second, the facilitator needs to ensure that ideas are addressed at a deep, conceptual level. Third, the facilitator needs to keep the group moving and ensure that everyone participates. These roles are critical in an asynchronous facilitation but enacting them will have some qualitative differences. In face-to-face tutorials, it is critical to get to the learning issues before a session ends. Session boundaries are not always clear in online PBL. Online systems need to consider timeframes and embedded activity structures for accomplishing PBL activities to create these boundaries. It is more difficult to keep an online group moving without the visual cues available in face-to-face interaction. Finally, it is likely that the facilitator has an additional role in asynchronous PBL –helping the group to converge rather than continuing to diverge. Understanding how to address these differences is critical in developing systems to support both students and tutors in asynchronous discussion.

PBL provides a well-described approach to constructivist learning however it is labor intensive and requires one trained facilitator for each group of students, which is not always practical. Often novices are asked to facilitate with very limited training. Research by Derry, Seymour, Steinkuehler, and Lee (2000) suggests that facilitation is quite difficult for novices. Novice tutors may not always know how and when to intervene appropriately. In the novice tutors' struggle to facilitate, they may be overly directive as they try to guide the group's agenda and have difficulty dealing with the group dynamics. The questions that the expert asks can be incorporated as procedural facilitations for the novice tutor by providing hints that suggest different questions that might be useful to serve different goals in different stages of learning. The analysis of the questions asked has been incorporated into a set of procedural facilitations for student tutors in an Educational Psychology class for preservice teachers. Figure 3 shows an example of one of the four prompt cards that a novice facilitator might use during hypothesis generation. These types of hints might be incorporated into an online tutor tool kit. As well, annotated examples of discourse could be provided to model how and when expert facilitators intervene and when they stand back and allow the group to work issues out among themselves. Although this includes very basic information about PBL, it provides concrete examples of questions that the facilitator could ask.

2) GENERATING MULTIPLE HYPOTHESES

Students should brainstorm their first instincts about:

IDEAS: how to solve the problem

FACTS: information we know about the problem and from their own knowledge

LEARNING ISSUES: information we need to know

ACTIONS: what we can do to start solving the problem

The scribe will begin to write down what the group says on the white board/ big paper.

Ask for clarification of terms written down in the FACTS and IDEAS columns.

EXAMPLES:

• What does that term mean?

• What does "expert" mean in this case?

If students can't clarify or define their ideas, these become LEARNING ISSUES

Goal: To help students understand what they don't know.

Figure 3. Example prompt card for facilitators

If trained facilitators are a limited resource, then a distributed PBL system might offer an alternative way to deal with this limitation (Steinkuehler et al., in press). As noted in the previous section, the analysis of expert facilitation can be used to provide tools to support novices in tutoring. Asynchronous collaboration might offer opportunities for students to be more reflective than they might be in a face-to-face conversation, enabling deeper learning conversations. However, the slower pace of asynchronous PBL might make some of the strategies described above difficult to implement. The slower pace gives the facilitator more time to respond to issues going on in the group but there is a real danger that the flow of the dialogue might be lost. In the face-to-face tutorial, the students made 3763 statements and asked 454 questions. Online, students take many fewer turns and there are significant time lags in students' responses. This suggests that there needs to be some adaptation to accomplish PBL asynchronously. A pilot study was conducted in Spring 2001 with 2 groups experienced in face-to-face PBL using the STEP PBL system.[2] The STEP PBL system is an innovative web site designed to support facilitated problem-based discussions of video-cases (Derry et al., 2001). The site has a student module which helps structure the students collaborative PBL, a tutor toolkit to provide resources for facilitation, an asynchronous environment for online collaboration, video case materials, and hypermedia information resources that cover learning sciences content. The student module included a whiteboard, as in traditional PBL and the asynchronous environment was a threaded discussion, For the pilot study, an experienced tutor facilitated the groups. Students would log on at different times and at irregular intervals. This posed a major challenge when the facilitator would ask a student to explain what they meant and the student might not log on for several days by which time the conversation was on another topic. As in other CSCL systems, the responses to students' posts and whiteboard entries need to be flagged so students can respond. One possible solution to this problem would be to have the system email the participants (including the facilitator) whenever there is a new post to remind them to log in. Because of the nature of threaded discussions, there need to be mechanisms that make the flow of the online discussions more transparent to the participants.

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[2] STEP website: http://www.wcer.edu/step

A CSCL system adapted for online PBL needs to have representations that support problem-based discourse. One way to accomplish this might be through anchored collaboration (Hmelo, Guzdial, & Turns, 1998) in which the whiteboard serves as an anchor for conversations. There needs to be a mechanism for the facilitator and other students to negotiate and discuss the contents of the whiteboards in an integrated fashion. Pilot work with the STEP PBL system suggests that integration of disparate workspaces is critical in distributing some of the facilitation onto the system and in maintaining the flow of the PBL tutorial session. A more integrated system might contain links and annotations that connect the discussion space to the whiteboard space.

Representations can also embody the goals of PBL. Consider the general goal of the facilitator to help students construct causal explanations that connect theories, data, and proposed solutions. Representational tools constrain student discourse to the extent that they support these goals—for example, a concept-mapping tool could support the construction of causal explanations to the extent that it is salient that students need to tie problems to solutions (Suthers, 2001). For example, the representation might emphasize what students need to observe in the problem (e.g., teachers goals, activity structures, assessments). Other visual representations might support other goals. It is critical that the various workspaces be integrated such that students map among the spaces, i.e., the whiteboard, asynchronous discussion, and other visual representations.

The sequence of activities is another way of offloading some of the facilitation task onto a system. Some of the expert facilitation strategies discussed above can be incorporated into the sequence of activities structured by the system. Students might be asked to generate summaries after some period of time and to compare their summaries and negotiate a joint summary of their problem representation and solution to date. The system might ask the students to update their hypothesis list whenever they log onto the system and ask them to explain why they are modifying their ideas as the expert facilitator does at regular intervals. As they are getting ready to log off, the system could have students compile a list of the learning issues they plan to research before the next time they log in. They might identify the resources that they used. This information could then be passed onto the facilitator as well as being posted to the group whiteboard as well as supporting the appropriate student activities.

CONCLUSIONS

Analysis of expert facilitation provides many valuable insights into what it means to do constructivist teaching. These insights fall into four categories. The first set of issues relate to how facilitators with varying levels of expertise can be trained and supported to be more like experts. The second is to provide guidance to offload facilitation functions onto an asynchronous PBL system. The third issue relates to embodying the goals and strategies of the expert facilitator into the visual representations that are available in the system. The fourth issue addresses how facilitating asynchronous and face-to-face discussions differ. These ideas for system design are hypotheses that need to be systematically tested to understand how PBL and other constructivist instructional models can be implemented to support productive discourse. Similar analyses need to be conducted of online facilitation to understand what it means to be an expert facilitator in an asynchronous environment.

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