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Goals and Strategies of a Problem-based Learning Facilitator

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Abstract

This paper describes an analysis of facilitation of a student-centered problem-based learning group. The focus of this analysis was to understand the goals and strategies of an expert facilitator in support of collaborative learning. This was accomplished through interaction analysis using video data and stimulated recall to examine two PBL group meetings. In this paper, we examine how specific strategies were used to support the PBL goals of helping students construct causal explanations, reason effectively, and become self-directed learners while maintaining a student-centered learning process. Being able to articulate these strategies is an important step in helping others learn the art of PBL facilitation. Keywords: facilitation, teaching strategies, pbl goals, interaction analysis

Introduction

Teaching is a complex cognitive activity, whether accomplished in a teacher-centered or student-centered classroom (Leinhardt, 1993). How one teaches and the strategies that are applied are intimately related to teachers' beliefs about the nature of the teaching-learning process (Schoenfeld, 1998). Teachers must juggle many goals as they coordinate pedagogical actions with various kinds of knowledge, such as subject matter knowledge, pedagogical content knowledge, and knowledge of individual students. For experts, teaching is a problem-solving context in which they must come to understand the meaning of students' ideas rather than just correct them (Lampert, 2001). This is especially true when teachers and students co-construct the instructional agenda in a student-centered environment such as problem-based learning (PBL). PBL is an instructional method in which students learn through solving problems and reflecting on their experiences (Barrows & Tamblyn, 1980). In PBL, the teacher's role is to facilitate collaborative knowledge

construction. In this paper, we first consider differences between student-centered and teacher-centered classrooms. We then present a study of a master PBL facilitator in order to identify the goals and strategies that characterize the teacher's role in guiding student learning. To place this in context, we will examine the cognitive activities involved in teaching and how teachers use different student-centered discourse strategies.

The goals and beliefs that teachers hold help frame the strategies that they implement. Schoenfeld (1998), through detailed analyses of expert and novice teachers, examined how teachers' knowledge, goals, and beliefs lead them to implement action plans. In his study, the novice teacher used a teacher-centered approach, asking known-answer questions, listening to students' responses, and then evaluating the responses. For example, when teaching a lesson on exponents, this teacher asked for the answer to a problem, the student responded correctly that he subtracted, and the teacher answered "OK," an evaluation of the response. The teacher asked the student what he subtracted and then elaborated on the student's correct response. All this proceeded according to the teacher's plan. This teacher believed that the students' responses provided springboards for teacher explanations. When students' responses diverged, his limited pedagogical content knowledge prevented him from adapting his plan. Later, on a more difficult problem, students' responses were not what the teacher expected, and the teacher had to generate an alternative example. The students did not understand the connection between the new example and the original problem, and they did not produce an answer that the teacher could use to build an explanation as in the earlier example. The teacher did not have an understanding of how incorrect student responses could be a window into their understanding and how these understandings could be used to focus discussions.

In contrast, Schoenfeld (1998) found very different results in the analyses of expert teachers (Jim Minstrell and Deborah Ball). Minstrell viewed learning as a sense-making activity and used questioning in productive ways. The lesson studied focused on issues of measurement in everyday contexts. Rather than being driven by a topic from the text, as with the novice teacher, the lesson was driven by problem-centered discussions. The teacher used questioning to guide student thinking. In particular, he used a technique called the reflective toss. In the reflective toss, the teacher takes the meaning of a student statement and throws responsibility for elaboration back to the student. He used these statements to help students clarify meaning, consider a variety of views, and monitor their own thinking. For example, as students were discussing how one might decide what number might be a best value from a list of measurements, a student noted that one number in a list was repeated several times. Minstrell asked the student for clarification and if there were any other repeated numbers. Another student proposed what was essentially a formula for a weighted average. This was unexpected. As Minstrell asked the students for further explanation, they developed a formula for calculating the

weighted average. Ball's classroom was more student-centered; her goal was to develop a particular type of intellectual community in which the pursuit of mathematical ideas was highly valued. She juggled competing goals as the students and teachers co-constructed the agenda. She started her elementary mathematics class by asking students for comments on the previous days' lessons. They then discussed issues related to their understanding.

The classroom of the novice teacher is typical of a traditional, teacher-centered classroom, in which the teacher asks most of the questions (Graesser & Person, 1994). The typical mode of discourse is the IRE pattern (Cazden, 1986) in which the teacher initiates a known-answer question, generally aimed at getting a student to display his or her knowledge, the student responds, and the teacher evaluates that response, as was observed in the novice teacher described by Schoenfeld (1998). Thus the goal focuses primarily on having students learn facts. Even in one-on-one tutoring, the tutor asks 80% of the questions (Person & Graesser, 1999). The student is active but tutors often work with curriculum scripts that drive the agenda.

In contrast, like the experts in Schoenfeld's study, inquiry teachers have goals that include higher levels of learning as well as remembering facts. A study of inquiry teachers identified several different types of goals and strategies that were used (Collins & Stevens, 1982). Inquiry teachers' goals encompassed having students learn theories and how they are derived. This included having students learn what questions to ask, how to make predictions from theories, and how theories and rules can be tested. These analyses showed that inquiry teachers use different kinds of strategies to achieve these goals. For example, they may select appropriate cases and counterexamples to encourage students to generate hypotheses, reveal misconceptions, and test ideas. Inquiry teachers tend to use questioning techniques to promote deep thinking; as a result 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. Minstrell and Ball (Schoenfeld, 1998) went beyond the description of inquiry teaching by helping students become aware of their own thinking, consistent with a view of learning as sense-making. PBL facilitation has much in common with student-centered inquiry teaching.

Student-centered learning has its foundation in social constructivist theories. This perspective contends that learning occurs as knowledge is negotiated among learners, often facilitated by a more knowledgeable group member and that students need to be active, intentional learners (Bereiter & Scardamalia, 1989; Palincsar, 1998). Instructional approaches derived from these perspectives use student-centered discourse as an instructional strategy. The role of the teacher becomes to guide the learning process rather than provide information.

In student-centered discourse, students drive the discussion and the teacher serves to scaffold the learning process (Collins, Brown, & Newman, 1989). In this model, the

agenda may be co-constructed by the students and teacher. Understanding how student-centered learning can be facilitated is important in being able to implement constructivist approaches such as PBL. One way to examine this is to analyze the goals and strategies of a master facilitator as well as to examine how these affect and are affected by the group discourse.[1] One might argue that to some extent the role of the facilitator is to create affordances for productive discourse (Greeno, 1998). PBL is a premier example of a student-centered learning environment as students co-construct knowledge through productive discourse practices.

Problem-based Learning

Problem-based learning is an active learning method based on the use of ill-structured problems as a stimulus for learning (Barrows, 2000). Ill-structured problems are complex problems that cannot be solved by a simple algorithm. Such problems do not necessarily have a single correct answer but require learners to consider alternatives and to provide a reasoned argument to support the solution that they generate. In PBL, students have the opportunity to develop skills in reasoning and self-directed learning. Empirical studies of PBL have demonstrated that students who have learned from PBL curricula are better able to apply their knowledge to novel problems as well as utilize more effective self-directed learning strategies than students who have learned from traditional curricula (Hmelo, 1998; Hmelo & Lin, 2000; Schmidt et al., 1996).

The PBL method requires students to become responsible for their own learning. The PBL teacher is a facilitator of student learning, and his/her interventions diminish as students progressively take on responsibility for their own learning processes. This method is characteristically carried out in small, facilitated groups and takes advantage of the social aspect of learning through discussion, problem solving, and study with peers (Hmelo-Silver, 2004). The facilitator guides students in the learning process, pushing them to think deeply, and models the kinds of questions that students need to be asking themselves, thus forming a cognitive apprenticeship (Collins et al., 1989). As a cognitive apprenticeship, PBL situates learning in complex problems (Hmelo-Silver, 2004). Facilitators make key aspects of expertise visible through questions that scaffold student learning through modeling, coaching, and eventually fading back some of their support. In PBL the facilitator is an expert learner, able to model good strategies for learning and thinking, rather than providing expertise in specific content. This role is critical, as the facilitator must continually monitor the discussion, selecting and implementing appropriate strategies as needed. As students become more experienced with PBL, facilitators can fade their scaffolding until finally the learners adopt much of their questioning role. Student learning occurs as students collaboratively engage in constructive processing. The dilemma for the facilitator is to provide affordances for this constructive processing

in the same way as Chi, Siler, Jeong, Yamauchi, and Hausman (2001) have argued that good tutors do.

Much research on facilitation has focused on the role of the tutor's subject matter expertise. Schmidt and Moust's (2000) review of studies of facilitation found three important, interrelated factors that contributed to effective facilitation. Effective facilitators had a "suitable knowledge base regarding the topic under study, a willingness to become involved with students in an authentic way, and the skill to express oneself in a language understood by students" (p. 47). However, this research was based on student and tutor ratings rather than on observations of facilitator performance. In a special issue of Discourse Processes (Koschmann, 1999), several researchers analyzed the same brief videotape clip of a PBL group meeting from different perspectives. Using conversation analysis, Koschmann, Glenn, and Conlee (1999) identified several moves that the facilitator made to scaffold the group's elucidation of their theory for the cause of a patient's medical problem. One move they identified was having the facilitator revoice what students said in a way that helped them move forward in the discourse (O'Connor & Michaels, 1992). A cognitive analysis found that the facilitator's moves helped scaffold an organized and coherent approach to reasoning and diagnostic inquiry (Frederiksen, 1999). A sociocultural analysis showed that the facilitator has an important role in creating a culture in which the participants work to reach consensus, validate each other's ideas, and establish norms (Palincsar, 1999). The facilitator played a pivotal role that advanced the PBL discourse and scaffolded learning.

These analyses make important contributions to understanding facilitation but they are based on a very brief slice of a single PBL meeting and do not allow analysis of the broader goals and strategies of the PBL facilitator. In this study, we examine two PBL group meetings that typically occur with a problem. The first meeting occurred before self-directed study for students to apply what they already knew and to figure out what they still needed to learn, and the second followed their self-directed study, in which the students applied their learning to their problem. We examine how the facilitator scaffolded learning through the use of general strategies that were chosen based on the facilitator's beliefs and goals for facilitation.

Method

Data Sources

The participants in this study were five third-year medical students who were experienced in PBL and a master facilitator. The students had two years of experience in a PBL medical curriculum. Howard Barrows (the second author) was the facilitator. Barrows is a physician with a specialty in neurology and an experienced PBL facilitator and medi-

cal educator. Students worked over 5 hours in 2 sessions, approximately 2.5 hours each, on the problem of a patient with pernicious anemia. The students knew each other but had not previously worked together as a group. The sessions were videotaped and transcribed.

Data Analysis

The first author reviewed the videotapes and transcripts for the general strategies that the facilitator used.[2] Exemplars of the strategies were identified and discussed with the facilitator. Using stimulated recall, the facilitator was interviewed regarding his goals and strategies while viewing the videotape. A number of episodes on the tape were selected as being representative of a particular kind of question being asked or strategy being deployed. The interview was unstructured. Often, the facilitator would just begin commenting on the episode. If he did not begin commenting or if additional information was desired, the facilitator was asked why he used a particular discourse move, what his goals were, what he had hoped to accomplish, and/or whether what he had expected occurred. This interview was audio taped and transcribed. The transcript was examined to identify the themes that emerged from this discussion as well as for discussion of other strategies reported in the literature.

In addition, interaction analysis (IA) was conducted to investigate the nature of facilitation strategies (Jordan & Henderson, 1995). This methodology assumes that knowledge is situated in social interactions—thus the facilitation goals and strategies were situated in the context of the facilitator's actions. IA involves collaborative viewing of videotapes to avoid the preconceived notions of a single researcher. IA examines the details of social interaction as they occur in practice. The IA session was conducted with the first author and an experienced cognitive scientist, a professor at a large Midwestern university, to further elucidate the data interpretation as they watched the videotape. Observations and hypotheses were generated while watching the tape. The tape was stopped and/or replayed whenever one of the participants noted something worthy of discussion. For example, on Tape 3 at 39:06 both analysts noted that the facilitator, on occasion, repeated what students were saying at important junctures. This led to identification of revoicing (O'Connor & Michaels, 1992), a strategy observed in other student-centered classrooms. These ideas were discussed and the first author summarized these ideas from extensive notes taken during the session. This report was later shared with the second analyst. These ideas were member checked with the facilitator to further ensure the reliability of interpretation.

Results: Analysis of Facilitation Goals and Strategies

The facilitator's overall educational goals for the students were for them to be able to (1) explain disease processes responsible for a patient's symptoms and signs and describe

what interventions can be undertaken, (2) employ an effective reasoning process, (3) be aware of knowledge limitations, (4) meet knowledge needs through self-directed learning and social knowledge construction, and 5) evaluate their learning and performance. The facilitator's performance goals were to (1) keep all students active in the learning process, (2) keep the learning process on track, (3) make the students' thoughts and their depth of understanding apparent, and (4) encourage students to become self-reliant for direction and information. The educational goals refer to what the students were expected to learn, whereas the performance goals refer to behaviors that the facilitator wanted to encourage (in support of the educational goals). The remainder of the results are organized in terms of strategies. Strategies can be used to achieve multiple goals that reflect a belief in learning as a collaborative sense-making activity and a belief that students bear much of the responsibility for their own learning.

The facilitator's overall strategy to help students address these goals was to use open-ended questions and the PBL process. The open-ended questions addressed most of the educational goals while keeping all students involved and making their thinking visible. The PBL process refers to the small group process that features ill-structured problems, hypothesis generation, revision, and evaluation, inquiry, decision-making, identification of learning issues, self-directed study, and reflection. The structured whiteboard helps guide this process. A list of some of the strategies that Barrows used as well as the goals they addressed are summarized in table 1, and we discuss several of these in the sections that follow.

Pushing for Explanations

One specific strategy that the facilitator frequently used was to push students for an explanation, as he did in the example below,[3] when Megan threw out the idea of multiple sclerosis as the cause of the patient's problem:

> Megan: . . . given . . . 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 30s and 40s, but it . . . can happen in an older person. So . . .
>
> Facilitator: And tell us what multiple sclerosis is.
>
> Megan: Um, multiple sclerosis is . . . a progressive and chronic debilitating disease um, where you get various points of sclerosis within the brain itself and it can affect . . . 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?

Table 1
Facilitation strategies

Strategy	Goals	How goals accomplished?
Use of open-ended and metacognitive questioning	E1–4, P1, P3, P4	General strategy to encourage explanations and recognition of knowledge limitations
Pushing for explanation	E1, P3 E3, P3, P4	Construct causal models Students realize limits of their knowledge
Revoicing	E1, P2 P1 P2	Clarify ideas Legitimate ideas of low-status students Mark ideas as important and subtly influence direction of discussion
Summarizing	E4, P1 P1 E1, E5, P3 P2 E5, P3	Ensure joint representation of problem Involve less vocal students Help students synthesize data Move group along process Reveals facts that students consider to be important
Generate/evaluate hypotheses	E2, E4, P2 E1, E2, P3, P4	Help students focus their inquiry Examine fit between hypotheses and accumulating evidence
Map between symptoms and hypotheses	E1, E2, P3, P4	Elaborate causal mechanism
Check consensus that whiteboard reflects discussion	E5, P2, P4	Ensure all ideas get recorded and important ideas are not lost
Cleaning up the board	E5, P4 P2 P2	Evaluate ideas Maintain focus Keep process moving
Creating learning issues	E4, P4	Knowledge gaps as opportunities to learn
Encourage construction of visual representation	E1, E5, P3	Construct integrated knowledge structure that ties mechanisms to observable effects

Key for Goals:

Educational goals for students:

 E1. Explain disease processes responsible for a patient's symptom and signs and what interventions can be undertaken.

 E2. To employ an effective reasoning process.

 E3. To be aware of their knowledge limitations.

 E4. To meet their knowledge needs through self-directed learning and social knowledge construction.

 E5. Evaluate their learning and performance.

Performance goals for facilitator:

 P1. To keep all the students active in the learning process.

 P2. To keep the learning process on track.

 P3. To make the students' thoughts and their depth of understanding apparent.

 P4. To encourage students to become self-reliant for direction and information.

Note: These codes for the goals are used throughout the results section

Note how the facilitator neither evaluated the student's response nor offered additional information at any time. This served to place the students' knowledge in public view and help them see the limits of their understanding (E3, P3[4]). It also pushed students towards thinking about how the disease arises and can cause a constellation of signs and symptoms (E1). Barrows noted that he tries to push for definitions and explanations in

> Those areas that I feel are really pertinent. . . . With every problem we have a whole suggested list of learning issues . . . so every facilitator knows exactly where the faculty feel they want the students to go. So your questions for clarification and for definition are . . . what is going to have the biggest payoff in terms of their learning in that particular area? So I let a lot of definitions and a lot of statements go. The ones I really pick on are the ones I really think are pertinent to what they are going to get out of this case.

This suggests that it is critical for the facilitator to always keep the learning goals in mind. These learning goals go beyond the specific problem that the patient actually has and include a broader conceptual space of associated conditions as well as the relevant basic biomedical sciences.

Revoicing

Another strategy observed was that of revoicing (O'Connor & Michaels, 1992), in which the facilitator restated what the students said.

> Megan: And another important um, hypothesis that's come [up] is a vitamin B_{12} 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 B_{12} deficiency . . .
>
> Donna: . . . I was just talking with my husband and . . . I was thinking that vitamin B_{12} wasn't so much if you treated it. But, I was reading that . . . neural deficits are irreversible. . . . So it is, you know. It does put in my mind it's . . . more of a serious . . .
>
> Facilitator: Now you people are saying B_{12} all the time and yet when you say we eliminated it, you're talking about pernicious anemia, right?

The facilitator addressed several goals here. First, he took the idea put forth by the students and clarified it for the group as he restated it. This helped the students in explaining the disease process (E1). At the same time, this helped keep the learning process on track as he provided the proper name for what the students were discussing (P2). Second, he has legitimated Donna's idea by placing it up for the group's consideration. Donna was a quiet but extremely thoughtful student and the facilitator recognized her with this move and kept her active in the discussion (P2). Third, he kept an important idea alive and subtly influenced the direction of the discussion (P2). The group had eliminated pernicious anemia from among many hypotheses on the whiteboard in the first session. Pernicious anemia was the cause of the patient's problem and was in danger of being lost from the discussion. By building on ideas that students had placed up for consideration, he encouraged them to rely on their own thinking (P4).

Summarizing

When the process stalled or when the facilitator needed to be sure that a quiet student was involved, he would ask a student to summarize. This served several goals. First, it checked the understanding of less vocal students and involved them in the discourse (E1, P1, P3). Second, it changed the flow of the discussion from being temporarily stalled to being more focused so it helped keep the learning process on track (P2). Third, it provided practice in case presentation, a skill that students will need as physicians (E2). Fourth, it allowed students to check their shared understanding and show what they thought was important (E4, E5, P1, P3).

Just before the next excerpt, the students were going through a number of signs and symptoms. Up to this point, Jim had been very quiet. The facilitator asked, "Jim, will

you summarize now what we know about this case? . . . And do it like you're presenting a patient on rounds." Jim then gave a detailed summary of the case, an indication that he was engaged in the discourse, if quietly so. This provided an opportunity for the facilitator to check for shared understanding as he asked the group, "Do you agree with his summary?" The group responded:

> Megan: . . . I do . . . But I might have included, um, the actual findings of the Romberg.
>
> Jim: Oh no. Again. That's the most important test.
>
> Megan: . . . The gait because I think that . . . broad based gait was very significant . . .
>
> Jim: I don't know why I didn't say that.
>
> Cheryl: I think the pain on . . . on the repeated pinprick is probably. . . . We don't know what it means but it's probably significant . . .
>
> Facilitator: You said she lost her balance. You were saying that's not it. It's this business here that you wanted him to say. You said on walking, she lost her balance.
>
> Jim: Yeah, at night she described that she lost her balance . . .
>
> Cheryl: Well she says it more. That, she described it as instability, which I mean, you're just making . . . she says instability as opposed to your interpretation of what she means. . . . Because I didn't interpret it as a loss of balance.

In this discussion, the group focused on how they interpreted an important finding and it was clear that different group members had different understandings. This provided an opportunity for students to negotiate a shared meaning. In addition, because summarizing patients is a professional skill, the facilitator provided opportunities for Jim to reflect on his performance and for other students to provide feedback (E5, P5). In the discussion that followed, Jim noted specific places where he might have improved and Jonathan provided additional constructive feedback as the students relied on themselves for evaluation. The summary then provided a springboard for the students to move through evaluating their hypotheses, as Barrows noted:

> So I used this mechanism of summarizing the case then going to the hypotheses as an excuse, because now saying "based on all this new information you've got, how do you like these hypotheses now?" Well as soon as they suggested changes, well then I say "why are you gonna make that change" and they'll bring out what they've learned and the rest will start discussing what they know about it and so indeed they are now reconstructing and structuring that information they have learned back to the patient problem . . .

Therefore, the summary here served many purposes and moved the students from a point where they were stalled to one where they were able to productively move forward in their problem solving. The summary moved them to begin examining the fit between their hypotheses and accumulated evidence (E1, E2, P3, P4).

Generating Hypotheses

Encouraging the students to generate hypotheses can help students focus their inquiry and become aware of the limitations of their knowledge. This is important in promoting effective reasoning and self-directed learning (E2, E4) as well as keeping the learning process moving along (P2). Without this, students may engage in unfocused data collection. For example, Barrows asked Cheryl to present her hypothesis, and a learning issue was created out of the hypothesis of diabetic neuropathy that she generated:

> Facilitator: You wanna . . . tell me what diabetic neuropathy is?
>
> Cheryl: . . . I can't really explain it well, but basically um, the high glucose levels, um can cause nerve damage and it's not uncommon for them, especially in the extremities to have loss of sensation. So, feet especially is one area where they lose sensation.
>
> Jim: . . . I heard that's . . . through glucose getting into the neuron and then getting converted to methanol.
>
> Cheryl: I believe so but I don't know.
>
> Jim: You don't know?
>
> Megan: Nonenzymatic glycosylation.
>
> Cheryl: Is it? I couldn't remember which
>
> Jonathan: It's just . . . Nonenzymatic gly, glycosylation . . . it's glycation.
>
> Megan: . . . All diabetics . . . eventually experience problems of diabetes. For example, the diabetic neuropathies, microvascular problems, um, that whole host of other things . . . it's definitely a possibility here . . .
>
> Facilitator: And so you're all comfortable in the mechanism of diabetic neuropathy? That was okay? You got it down cold.

The facilitator ended the muddled discussion by asking the students if they were really comfortable in their understanding and the students noted their need to learn more. This prompted the students to monitor their understanding, realize that their understanding was insufficient, and recognize the need to learn more about the mechanism of diabetic neuropathy (E4, E5, P4). Thus, diabetic neuropathy ended up on the list of learning issues to be addressed by self-directed learning.

Using the PBL Routine: Cleaning Up the Boards

One way that the facilitator guided students to evaluate hypotheses was by taking advantage of the PBL routine, in particular, the structured whiteboard, where the group's hypotheses, accumulated information about the problem, and list of information to be pursued during self-directed study were recorded. In this next example, during the second session, Barrows asked students to clean up the board: ". . . let's clean up on a few other things . . . is that blood pressure very significant or not? Why?" This led Jonathan to talk about high blood pressure (i.e., hypertension) and guidelines for managing it.

> Jonathan: . . . [reads aloud from handout] . . . "treatment in elder patients should be the same as in younger patients to less than 140/90[5] if at all possible." . . . They talk about how because you get . . . less . . . compliance of the vessels with older patients, um, the difference between the systolic versus diastolic is probably more important than either one alone . . . And . . . she has elevated systolic without so much elevated diastolic. So I, it's actually worse for her cardiovascular risk. . . . But since we only have one value . . . we need to have her come back . . . to evaluate her or refer her for care within one month, according to the table on the top. 'Cause she fits in the systolic of 160 . . .
>
> Jim: I mean that's . . . significant . . . . how much weight does this article hold? Like what kind of research was done? . . .
>
> Jonathan: Well, my understanding is this has countless numbers of people involved . . . this is like the authoritative source for hypertension . . .
>
> Cheryl: So these are the guidelines that are implemented.
>
> Jim: This is it, what we should follow . . .

Although this was not the major issue in the case, hypertension was something that the students were concerned about. They evaluated their hypothesis by first examining some abstract information from the guidelines that Jonathan distributed. After reading those, he began to map the patient's symptoms to the guidelines, supporting his hypothesis about hypertension (E1, E5). This required sophisticated reasoning (E2). But then Jim raised the question of how trustworthy his information was and Jonathan responded by noting that it was a very large study, so Jim now agreed that this was valid (E5, P4). Thus in this segment, the simple act of cleaning up the board led students to evaluate their hypotheses by mapping patient data to their hypothesis, and to consider the value of evidence that one of their group members was using. We also note here that it was a student who questioned the reliability of the information, providing an example of how the students begin to take on some facilitation functions. It also helped move the learning process along as students deliberated over hypotheses, ruling some out and considering the importance of others during their group discussions (E4, P2, P3, P4).

Additional Strategies

Other ways that the facilitator encouraged students to map between symptoms and causal mechanisms included asking students why they ordered particular tests, and late in the second session, asking them to draw a flowchart that represented their understanding. He noted that

> . . . is a very valuable tool because it allows them to integrate everything they've learned into a very careful structure from the very basic mechanisms all the way to the symptoms. But [it] also will then reveal where there are gaps or holes in their thinking where they don't have an answer that makes sense or where they may need to do more learning . . . bringing everything they've learned together around the problem and to really construct an understanding.

Drawing the flowchart elicited the biochemical mechanisms that accounted for the signs and symptoms during an extended discussion. Drawing an additional anatomic diagram brought their discussion from the biochemical level to a more macroscopic level of what was happening in the spinal nerve tracts. This visual representation thus helped the students create an integrated and coherent understanding. Constructing these representations addressed a number of educational goals for the students and performance goals for the facilitator. In particular, it addressed the goal of explaining how the disease process accounted for the patient's signs and symptoms (E1) and made their depth of understanding visible (P3). The drawing made salient where there were gaps in their understanding that needed to be explained and often led to a great deal of monitoring of their performance (E5).

The facilitator is always looking for moments in which he or she can use any of a variety of strategies to (1) keep the process going with all students involved, moving in productive directions, (2) help make students' understanding and thinking transparent, and (3) guide them towards the curriculum's educational goals. These strategies are not scripted in advance but are rooted in the students' discussions while keeping the overall goals in mind. The interview data makes it clear that goals are being juggled based on what is happening in the tutorial session.

Discussion

Facilitation, like other forms of teaching, involves a dynamic interaction of the teacher's beliefs, goals, and knowledge. Barrows had a strong belief in the importance of students' taking responsibility for their learning and the importance of their constructing useable knowledge, as his comments make clear. He shared with many inquiry-oriented teachers a view of learning as a sense-making activity. As a neurologist, he had a deep understanding

of the subject matter involved in the problem and, as an experienced medical educator and PBL facilitator, knowledge about how the problem might unfold. His general goal was to have students construct causal explanations and he had a repertoire of strategies and techniques to support him in that goal.

Like other inquiry teachers (Collins & Stevens, 1982), Barrows orchestrated group discussions through questioning, but unlike the inquiry teachers, his goal was for students to internalize those metacognitive functions (P4). Elsewhere, we have shown that these students asked more than half of the questions in the tutorial sessions, including metacognitive and causal questions (Hmelo-Silver & Barrows, 2005). The facilitator's questions built on student thinking and placed responsibility for sense-making with them, much like Minstell's reflective toss (Schoenfeld, 1998). Barrows selected his strategies on the fly, as he used the students' thinking as a basis for gently guiding them through the problem. In one instance when a student noted a symptom as significant, Barrows took that as an opportunity to help the group make their thinking visible and address several goals:

> . . . I want to find out . . . what is the depth of their understanding and I want them to recognize what they understand. But sometimes I'm doing, I think in this instance to bring an issue up for the group to really work with and understand how it fits everything together. So I think I did this more as an attempt to . . . nail down an important point for them to recognize that they had developed themselves . . . I didn't know [if they knew that] so that's why I asked the question . . .

Clearly, these instances provided opportunities to build on and guide students' thinking in the moment. They could not be scripted in advance, as goals and strategies were juggled in response to the group discussion.

The triggering conditions for the use of strategies were fluid, as Barrows consciously avoided letting students know when they were on the right track; he left that responsibility with them. For example, he may have pushed students to explain their thinking on most of their initial hypotheses. While he may have avoided this for something peripheral, he would always push on the hypotheses that were most likely to account for the patient's problems. He did this frequently enough that it did not clue the students in to the "right answer."

The PBL setting creates a cognitive apprenticeship that acculturates students into the thinking practices of medicine. Through his actions, Barrows modeled appropriate ways of thinking about patient illnesses in terms of their underlying causal mechanisms. By making the students' thinking visible, their ideas became objects for discussion, reflection, and revision. Barrows pushed students' thinking to deep levels as he continually asked them to explain themselves. The students appropriated part of the facilitator's role

as they questioned each other (as in the hypertension example presented earlier). They developed the useful habit of questioning their own thinking. The summarizing strategy provided an opportunity for the group to monitor their progress (Brown & Palincsar, 1989).

Implications for Other Domains

Although the example here is set in the context of medical PBL, the lessons are applicable to PBL in other domains. Most of the goals, except for explaining the disease process (E1), are domain-general. Even this first goal can be adapted to a more general form such as creating causal explanations. In Hmelo-Silver (2000), these goals and strategies were made explicit in prompt cards that student-facilitators used in an educational psychology course. In that course, one goal was to solve classroom problems using educational psychology principles to explain their solutions. Some of these goals and strategies have since been incorporated into technology support for PBL in educational psychology and used to provide advice for beginning facilitators (Hmelo-Silver, Derry, Woods, DelMarcelle, & Chernobilsky, 2005). We believe that, regardless of discipline, teaching about appropriate goals for PBL and providing suggestions for effective strategies might be fruitfully incorporated into facilitation workshops.

Although these strategies may need to be adapted for different disciplines, they provide a useful starting point. Our research suggests that it is important for facilitators to make explicit their educational and performance goals and to identify strategies that can be used to achieve those goals. For example, Hmelo-Silver (unpublished data) frequently accomplishes her explanatory goal by asking students, "What is the psychological rationale for your idea?" But she has also observed that there are other, more explicit strategies that have served to derail a group's conversation. It is critical for facilitators to be reflective in terms of evaluating how effective strategies are in achieving desired goals.

Conclusions

As we noted at the beginning of this article, teaching is a complex task, and all the more so in a student-centered learning environment such as PBL. Driven by his beliefs about the importance of student reasoning and self-directed learning, and his confidence in his students' capability as well as his content expertise, Barrows and the students co-constructed an agenda as he built on the group's thinking and the group built on his facilitation. This study demonstrated that an expert facilitator has a repertoire of strategies that can be

flexibly adapted to meet the goals of PBL. Barrows used modeling, scaffolding and fading progressively as the students grew more responsible for their own learning and began questioning each other. He modeled the questions students should be asking themselves until they appropriated these questioning strategies themselves. Although there are limits to what can be generalized from a single case, our analyses are consistent with other research on using student-centered discourse as an instructional strategy (e.g., Schoenfeld, 1998). We identified a number of specific strategies and some of the goals that they might serve. Being able to articulate these strategies is an important step in helping new PBL facilitators learn the art of facilitation.

Acknowledgments

Notes

1. We define a master facilitator as one with extensive experience and recognized expertise. The master facilitator studied here was instrumental in the development of PBL and has 30 years experience facilitating and 25 years conducting facilitation workshops.

2. Elsewhere, we report on the fine-grained analysis of this video data (Hmelo-Silver & Barrows, 2005)

3. Transcripts have been edited for readability and length. All omissions in the transcript are indicated by an ellipsis (. . .).

4. These codes indicate which goals are addressed, based on the key in table 1.

5. This refers to the measurement of blood pressure with the numerator being the systolic measurement (the pressure in the arteries during the heart's contraction) and the denominator being the diastolic pressure (the pressure during relaxation of the heart).

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