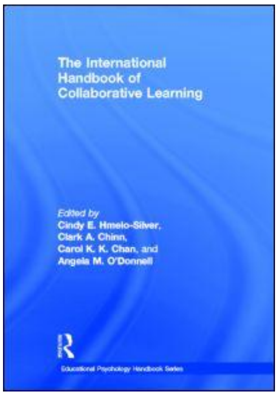

The International Handbook of Collaborative Learning

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PROBLEM-BASED LEARNING

An Instructional Model of Collaborative Learning

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Problem-based learning (PBL) is a learner-centered pedagogical approach in which students engage in goal-directed inquiry. In PBL, students work collaboratively to learn through solving complex and ill-structured problems (Barrows, 2000; Hmelo-Silver, 2004). They engage in self-directed learning (SDL) and then apply their new knowledge to the problem and reflect on their learning of the content and strategies employed. The teacher's role changes from one of telling to one of facilitating the learning process. More specifically, the goals of PBL include helping students develop (a) flexible knowledge, (b) effective problem-solving skills, (c) SDL skills, and (d) effective collaboration skills.

PEDAGOGICAL GOALS OF PROBLEM-BASED LEARNING

The first goal of PBL, constructing flexible knowledge, refers to knowledge that is coherently organized around the deep principles in a domain (Chi, Feltovich, & Glaser, 1981). Learners need to understand when and why such knowledge is useful (Bransford, Brown, & Cocking, 2000). Flexible knowledge develops as people apply their knowledge in a range of problem situations (Cognition and Technology Group at Vanderbilt [CTGV], 1997; Kolodner, 1993).

For learners to develop usable knowledge and skills, learning should be situated in problem-solving contexts (e.g., Capon & Kuhn, 2004; Hmelo, 1998; Perfetto, Bransford, & Franks, 1983). Moreover, discussing problems in a PBL group prior to accessing information activates relevant prior knowledge and facilitates the construction of new knowledge (Schmidt, DeVolder, DeGrave, Moust, & Patel, 1989).

The second goal of developing effective problem-solving skills refers to the ability to exercise appropriate reasoning strategies. Different strategies may be appropriate for different domains and for different problems. For example, hypothetical-deductive reasoning is an appropriate strategy for medical problem solving whereas analogical or case-based reasoning may be appropriate in many design domains such as architecture

A third goal of PBL is to support the development of lifelong learning skills, which means helping students become self-regulated learners (Zimmerman, 2002). To accomplish this, learners must have a metacognitive awareness of what they do and do not understand. During the PBL process, students set learning goals for themselves as they identify what they need to learn, how to reach their goals, and evaluate whether or not their goals have been attained.

The fourth goal of PBL is learning to collaborate, which means productively participating in small groups. This encompasses establishing common ground, resolving discrepancies, negotiating the actions that a group is going to take, and coming to an agreement (Barron, 2002). PBL allows for an open exchange of ideas and engagement of all group members (Cohen, 1994; O'Donnell, 2006).

FEATURES OF PBL

There are several key features of PBL that help to support these goals. First and foremost is the student-centered tutorial process that is at the heart of problem-based learning.

The PBL Tutorial Process

Typically, the tutorial process begins by presenting a group of students with minimal information about a messy, ill-defined problem (Barrows, 2000). These problems may be presented as a narrative, a paper or computer-based problem simulation, or in a range of other formats (Hmelo-Silver, 2004). From the outset, students must engage in some form of inquiry to obtain additional problem information (Torp & Sage, 2002). For example, when middle school children were asked to build artificial lungs, they performed experiments to determine how much air the lungs had to displace (Hmelo, Holton, & Kolodner, 2000). For teacher education students, videos of classroom practice may provide rich problem contexts (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006). As learners work through a problem, they may pause to reflect on the data they have collected so far, generate questions about that data, and hypothesize about underlying causal mechanisms that might help explain it. The students then identify concepts they need to learn more about in order to solve the problem (i.e., "learning issues"). After considering the problem with their naïve knowledge, the students divide and independently research the learning issues they have identified. They then regroup to share what they learned, reconsider their hypotheses, or generate new hypotheses in light of their new learning, as shown in the cycle displayed in Figure 21.1. When completing the task, learners reflect on the problem in order to abstract the lessons learned, as well as how they performed in self-directed learning and collaborative problem solving.

Typically, in the PBL model, students use whiteboards to help scaffold their problem solving (Hmelo-Silver, 2004). The whiteboard is divided into four columns: facts, ideas, action plans, and learning issues. These columns help the learners keep track of where they have been and where they are going. The four columns scaffold learning by helping to communicate and guide the learning process (Dillenbourg, 2002; Hmelo-Silver,

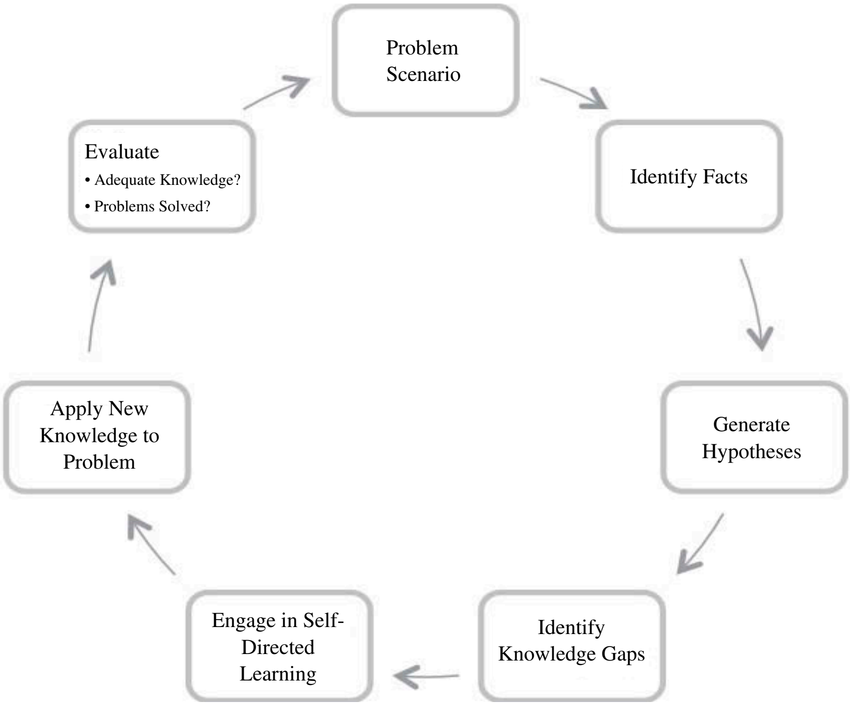

Figure 21.1 The PBL Cycle

2006). The whiteboard serves as a focus for students to negotiate ideas and co-construct knowledge.

The other key aspects of the PBL process, the problem, facilitation, collaboration, and reflection, are all embedded within the PBL tutorial and help provide a mechanism for PBL to achieve its goals.

The Role of the PBL Problem

Both research and practical experience provide suggestions for the characteristics of good problems (Cohen, 1994; Jonassen & Hung, 2008; Kolodner, Hmelo, & Narayanan, 1996). To promote flexible thinking and to be group-worthy, problems need to be complex, ill structured, and open ended; there should be multiple solution paths (Jonassen & Hung, 2008). To support intrinsic motivation, problems must be perceived as realistic by the students, resonate with their experiences, and motivate their need to know. When possible, problems should provide feedback that allows students to evaluate their success as learners, problem solvers, and collaborators. Such problems should foster conjecture and argumentation. Good problems help students become engaged in the PBL process right from the beginning based on their initial understanding. Generative problems often require multidisciplinary solutions. For example, planning a trip on the Appalachian Trail requires using knowledge from several content areas, which allows students to see how different categories of knowledge are useful tools for problem solving.

The ill-structured problems used in PBL can serve as the basis for high levels of problem-relevant collaborative interaction; however, groups may need good facilitation to make this interaction productive (Kapur & Kinzer, 2007; Van Berkel & Schmidt, 2000).

Although in studies of PBL, the predominant type of ill-structured problem has been diagnosis (e.g., medical students need to diagnose the cause of a patient's problem), other types of problems have been successfully used. Walker and Leary (2009) found that the greatest achievement effects were for problems that were classified as design problems and strategic performance problems. A design problem might ask learners to design artificial lungs or an instructional plan (e.g., Derry et al., 2006; Hmelo, Holton, & Kolodner, 2000). A strategic performance problem might ask learners to act in complex, real time situations in which they have to employ and adapt tactics as appropriate to situational demands (Walker & Leary, 2009). A teacher implementing a lesson and having to deal with student ideas on the fly would be an example of such a problem.

The Role of the Facilitator

PBL facilitators play a key role in modeling the problem solving and self-directed learning skills needed when self-assessing one's reasoning and understanding, consistent with a cognitive apprenticeship model of learning (Collins, 2006). Facilitators are expert learners, modeling good strategies for learning and thinking rather than providing content knowledge. As portrayed in the PBL process earlier, facilitators progressively fade their scaffolding as students become more experienced with PBL and take increased responsibility for their collaborative learning (Hmelo-Silver & Barrows, 2008). The facilitator agenda includes both moving the students through the stages of PBL and monitoring the collaborative learning process—assuring that all students are involved and encouraging them to make their own thinking visible and to comment on each other's ideas (Hmelo-Silver & Barrows, 2006, 2008; Koschmann, Myers, Feltovich, & Barrows, 1994). The PBL facilitator guides the development of higher order thinking skills by encouraging students (and the group) to justify their thinking, and externalizing self-reflection by directing appropriate questions to individuals. Expert facilitators accomplish their goals through the use of a variety of strategies (see Hmelo-Silver & Barrows, 2006 for a list of examples) that often involve the use of open-ended and metacognitive questioning (Hmelo-Silver & Barrows, 2008). These strategies build on student thinking and help catalyze and focus discussions in subtle but productive ways. Facilitators progressively fade their support as students assume more responsibility for their collaborative learning (Collins, 2006; Hmelo-Silver & Barrows, 2008).

Collaborative Learning in PBL

Learning in PBL is a fundamentally collaborative experience where problem solving and knowledge building require dialogue amongst group members. One assumption of PBL is that the small-group structure helps distribute the cognitive load among the members of the group, taking advantage of group members' distributed expertise by allowing the group members to become "experts" in particular topics. This expertise develops as learners divide up learning issues and conduct self-directed research that they share with the rest of the group. Thus, the whole group is needed to tackle problems that would normally be too difficult for each student alone (Pea, 1993; Salomon, 1993). Moreover, through this process of interaction and dialogue, learners (e.g., preservice teachers, medical students) in PBL become enculturated in their professional community. Through this process members learn the language, issues, and explore tools and resources available to them, which will help them solve relevant problems. Furthermore, research suggests that the small-group discussions and debate in PBL sessions enhance higher order thinking and promote shared knowledge construction (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Vye, Goldman, Voss, Hmelo, & Williams, 1997).

In PBL groups, the students often work together to construct collaborative explanations, but collaboration in PBL does not necessarily come easily. In the traditional PBL model, a facilitator helps accomplish this. Hmelo-Silver, Chernobilsky, and Nagarajan (2009) presented a case study demonstrating that students can learn to collaborate better with reflection by the students and guidance by the facilitator. Emergent leadership in PBL groups can also be important for supporting collaboration as students take responsibility for facilitating themselves when PBL is implemented in larger classes (Gressick & Derry, 2010; Hmelo-Silver, Katic, Chernobilsky, & Nagarajan, 2007). In the absence of a dedicated facilitator, several techniques can foster productive collaboration. Scripted cooperation, reciprocal teaching, guided peer questioning, and the use of student roles have all been used to support effective collaborative learning with K–16 students and might offer possibilities for supporting collaboration in PBL (Herrenkohl & Guerra, 1998; King, 1999; O'Donnell, 1999; Palincsar & Herrenkohl, 1999; see O'Donnell and Hmelo-Silver Introduction this volume; Fischer et al., chapter 23 this volume).

Collaborative inquiry and problem solving does not necessarily happen without support (Ertmer & Simons, 2006; Schmidt, Loyens, & van Gog & Paas, 2007). Rather, this collaboration needs to be facilitated by PBL tutors who have both content knowledge and communication skills**.** Zhang, Lundeberg, McConnell, Koehler, and Eberhardt (2010) found that questioning assists teachers in the development of collaborative inquiry. In particular, questions such as those that ask for clarification, elaboration, and connection to classroom practice lead to better content understanding. In another study of PBL in teacher professional development, Zhang, Lundeberg, and Eberhardt (2011) demonstrated that questioning and revoicing were the most common strategies used by expert facilitators, but that often a combination of strategies was needed to help support the progression of ideas during collaborative discussions.

Reflection for Learning and Transfer

Reflection is a critical component of PBL and is important for constructing generalizable knowledge (Salomon & Perkins, 1989). This reflection must help the learner understand that the tasks they are doing are in the service of the questions they have asked, and that these questions arise from the learning goals they have set for themselves (Bereiter & Scardamalia, 1989). Reflection helps students: (a) relate their new knowledge to their prior understanding, (b) mindfully abstract knowledge in order to understand the "big ideas" of a domain, and (c) understand how strategies and content might be applied, extended, and constructed. PBL incorporates reflection throughout the tutorial process and when completing a problem. Students periodically reflect on the adequacy of their hypothesis list and their own knowledge relative to the problem. After each problem, students reflect on what they learned, how they functioned as part of a team, and their effectiveness as self-directed learners. As students make inferences that tie the general concepts and skills to the specifics of the problem that they are working on, they construct more coherent understanding (Chi, Bassock, Lewis, Reimann, & Glaser, 1989). The reflection process in PBL helps students make inferences, identify knowledge gaps, and prepares them for transfer.

Often groups need help to reflect on their learning (Hmelo-Silver, 2000). A dedicated facilitator can support student reflection, but in larger groups and with younger learners, there are other techniques that may be helpful. One approach to dealing with this is the use of structured journals (Puntambekar & Kolodner, 1998). Another approach is to mix both small-group and large-group discussion of process and content (De Simone, 2008, 2009).

RESEARCH ON PBL OUTCOMES

With an understanding of the features and affordances of PBL as a model of collaborative learning, we next consider what the research says with respect to its goals for PBL. We look in turn at how PBL helps develop (a) flexible knowledge, (b) effective problem-solving skills, (c) SDL skills, and (d) effective collaboration skills. We group these first goals together because they are often examined in the same research studies.

Flexible Knowledge and Problem Solving

In the medical context, PBL students perform equal to or slightly worse than traditional medical students on tests of basic sciences but consistently better on clinical medicine tests (Albanese & Mitchell, 1993; Goodman et al., 1991; Mennin, Friedman, Skipper, Kalishman, & Snyder, 1993; Schmidt, van der Molen, te Winkel, & Wijnan, 2009; Vernon & Blake, 1993). There are mixed results on problem-solving tasks (e.g., Hmelo, 1998; Patel, Groen, & Norman, 1993). Patel et al. (1993) asked traditional and PBL medical students to provide diagnostic explanations of a clinical problem. PBL students' explanations, although containing more errors, were also more elaborated than those of the medical students in traditional curricula. More recent results are more positive. When studied over the first year of medical school, students in a PBL curriculum were more likely to construct accurate hypotheses and use science concepts than students in a traditional curriculum (Hmelo, 1998). The accuracy effect appears to be robust. When students in PBL and traditional curricula were compared in terms of diagnostic accuracy for 30 case vignettes, PBL students were more accurate than students in a traditional curriculum (Schmidt, Machiels-Bongaerts et al., 1996). Thus, studies in medical schools tend to show that PBL students are able to construct knowledge, if tasks are used that tap knowledge in problem-solving contexts (e.g., Gijbels, Dochy, Van den Bossche, & Segers, 2005; Hmelo, 1998; Schmidt, Machiels-Bongaerts et al., 1996) rather than multiple-choice measures (Albanese & Mitchell, 1993; Goodman et al., 1991; Vernon & Blake, 1993).

Research on the use of PBL in teacher education has proliferated in the past 10 years. Teachers face complex and diverse pedagogical and classroom problems, and they tend to bring their personal experiences and beliefs to these problems and have yet to learn to draw upon research and theories of learning (Arvaja, Salovaara, Häkkinen, & Jävelä, 2007; O'Donnell, 2004). Because of its emphasis on inquiry and knowledge application, PBL can be used to assist preservice teachers in their pedagogical problem solving. There is research evidence demonstrating that in comparison to a group of preservice teachers who served as controls, those preservice teachers who learned through PBL were significantly better able to work through diagnosis-solution pedagogical problems (De Simone, 2008, 2009). Both of these studies repeatedly showed that preservice teachers were able to: (a) provide feasible solutions; (b) evaluate the solutions; and (c) use educational concepts as support for their analysis of the pedagogical situation. PBL can help teachers to make considered decisions and navigate through the teaching and learning issues that they confront.

In a study that demonstrated how technology could support PBL in teacher education, Derry, Hmelo-Silver, and colleagues (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006; Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009) conducted a 3-year study in educational psychology courses using a hybrid online and face-to-face PBL environment consisting of multimedia cases and an electronic notebook to highlight important issues and use as a springboard for discussion. These were compared to a standard comparison class using lectures and face-to-face interactions. The results demonstrated that those using the technology-supported hybrid PBL were better able to transfer educational psychology concepts to analysis of a novel video case than those who used a more traditional approach. The transfer of problem solving skills and concepts is a pivotal goal of learning and the results here suggest that PBL can meet that goal.

PBL has been applied in undergraduate education as well. In a study of a PBL engineering course in sustainable technology, students used PBL in multidisciplinary teams (Hmelo, Shikano et al., 1995). The students demonstrated a significant increase in both knowledge and problem solving. When PBL was used to teach statistical reasoning to undergraduates, Derry, Levin, Osana, Jones, and Peterson (2000) found that students showed significant learning gains for some, but not all, of the course content.

Although PBL appears to support learning in professional and undergraduate educational contexts, there has been less work with other populations, particularly younger learners. In work with gifted high school students, Gallagher and Stepien (1996) found that PBL students scored higher on a multiple-choice test than traditionally instructed students. Comparing traditional and problem-based instruction in high school economics, Mergendoller, Maxwell, and Bellisimo (2006) found that across multiple teacher and schools, students in the PBL course gained more knowledge than the students in a traditional course.

Another approach used design problems with a heterogeneous population of sixth grade students. Hmelo, Holton, and Kolodner (2000) developed a PBL unit that involved students designing artificial lungs and demonstrated that PBL students showed greater gains on both short answer tests and mental model analyses than students in comparison classrooms. However, students in the PBL class had some misunderstandings at the end of the 3-week unit. This suggests that adaptations such as additional scaffolding and just-in-time minilessons might be needed to use PBL in developmentally appropriate ways.

Becoming Self-Directed Learners

Proponents of PBL make claims about preparing lifelong learners by explicitly stressing self-directed learning (SDL) as part of the PBL design. Becoming a self-directed learner is a complex and multifaceted process, and students' SDL strategies evolve over time (Evensen; 2000; Evensen, Salisbury-Glennon, & Glenn, 2001). It is worth noting that SDL as defined in the PBL and adult learning research literature shares many characteristics with self-regulated learning (SRL); however, there are also some key differences (Loyens, Magda, & Rikers, 2008; Zimmerman & Lebeau, 2000). Loyens et al. argue that SDL is broader than SRL and is a design feature of learning environments that require full learner control on learner-defined tasks (but see Loyens et al., 2008 for a full discussion of the relationship between SDL and SRL).

Students' approaches to learning from problems differ qualitatively depending on their degree of self-regulation. Ertmer, Newby, and MacDougall (1996) found that students who were low self-regulated learners (SRL) had difficulty in adapting to the kind of learning required in PBL. Hmelo and Lin (2000) demonstrated that PBL students transferred the reasoning strategies from their problem solving into their SDL as they used their hypotheses to guide their SDL.

When comparing traditional and PBL medical students in terms of the learning resources used, Blumberg and Michael (1992) found that PBL students were more likely to use self-chosen learning resources whereas students in the other curriculum used faculty-chosen resources. In a technology-enhanced PBL course for preservice teachers, Jeong and Hmelo-Silver (2010) found that there was great variability in how preservice teachers used resources in their SDL. Students who used a range of resources and went beyond those resources that were most obvious, and processed those resources most deeply were most likely to demonstrate high achievement.

A recent review of the literature demonstrated that self-directed learning is a developmental process. Loyens, Magda, and Rikers (2008) found that across many studies of postsecondary students, students became more self-directed learners as they advanced in their PBL programs. The review also noted that although SDL processes can be learned, these skills don't necessarily develop without support. In a descriptive study of SDL as it occurred in a naturalistic context in a Singapore polytechnic school, Yew and Schmidt (2009) found that facilitators often provided support to help students plan their SDL research and reporting and make connections between ideas and the problem statement. This support generally took the form of open-ended questions that invited the students to identify what they would research and present as well as asking them how what they had learned would connect to the problem. More studies like these are needed to better understand how SDL unfolds as a collaborative, self-regulated, and constructive process.

Learning to Collaborate

Helping students to become effective collaborators is one of the main goals of PBL. Most of the research in this area has focused on the factors that affect how well students learn collaboratively. This is particularly important because group functioning affects learning outcomes and intrinsic motivation (Schmidt & Moust, 2000). They found that collaboration was affected by the quality of the problem and facilitator functioning.

Students in PBL curricula are aware of the importance of collaboration (DeGrave, Boshuizen, & Schmidt, 1996). Effective collaboration can lead to knowledge construction as students construct joint explanations. An analysis of PBL tutorial sessions found that student discourse often focused on responding to and refining ideas that had been proposed (Hmelo-Silver & Barrows, 2008). In PBL, students are encouraged to attend to collaboration processes through reflection and the interdependence of learning within the group. But students do not necessarily know how to deal effectively with the collaborative aspects of PBL (Abrandt Dahlgren & Dahlgren, 2002; Evensen et al., 2001).

We still need to better understand whether and how students in PBL learn to collaborate. There is evidence that students do work together to provide collaborative explanations (Hmelo-Silver & Barrows, 2008) as well as to coconstruct knowledge during self-directed learning (Yew & Schmidt, 2009). There is also evidence that the collaboration in tutorial groups is a key factor in student learning and motivation but that not all groups collaborate well (Derry et al., 2006). There has been progress in understanding the factors that affect the quality of collaboration. The quality of collaborative discussions is affected by the nature of the problem (e.g., structure, relevance, interest), the facilitator, the group composition and experience, and participation equity (Kapur & Kinzer, 2007; Zhang, Lundeberg, Koehler, & Eberhardt, 2008).

There is at least one recent study that addresses the issue of collaboration directly. In an adaptation of PBL called challenge-based learning, O'Mahony and colleagues (2012) compared collaborative discourse in a traditional and problem-based module for an aerospace workplace. The results demonstrated that the learners in the challenge-based course engaged in higher quality collaboration than students in the traditional course, and that this effect on participation persisted even when the instructor returned to a lecture mode. Their analyses demonstrated that the quality of the collaboration improved over time moving from the participants' initial efforts at establishing what they knew with the group to what O'Mahony et al. called knowledge-sharing exchanges. These were conversations in which group members asked questions of each other and worked collaboratively to address the questions. The results of this study suggest that through PBL experiences, students can learn to collaborate, although additional research is needed to study this in other settings.

To summarize, in answer to our question: Has PBL achieved its stated goals? There is increasing evidence that PBL is effective for problem solving and for constructing flexible knowledge. We also know that dialogue scaffolded by an expert PBL and content facilitator does facilitate collaborative inquiry, which is important for problem solving and transfer. We are still lacking an adequate research base regarding collaboration as an outcome of PBL but we do have evidence of promise. In the next section, we describe adaptations of PBL for different settings and how these adaptations can foster collaborative inquiry.

ADAPTATIONS OF PBL

The traditional model of PBL has been successful in the training of medical doctors. For this model, certain criteria must be met: PBL must be integrated across the curriculum; the focus must be on issues or problems instead of subjects; class sizes must be very small; and students must be high achievers. However, alternative models are needed when one or more of these factors are not present or other factors intervene resulting in resource challenges. An important issue in moving beyond this model of PBL is one of scale. The role of the facilitator is extremely important in modeling thinking skills and providing metacognitive scaffolding as well as providing support for collaboration.

Hmelo-Silver (2000) and De Simone (2008, 2009) have successfully managed to facilitate multiple groups using a wandering facilitation model, with facilitators rotating from group to group, adjusting the time spent with each of the groups in the classroom according to the needs of the group. By using large tear sheets hung on the classroom walls, they were able to dynamically assess the progress of each of the groups and adjust facilitation efforts accordingly.

Technology can also be used to extend skilled facilitation (Derry et al., 2006). Students may also be called upon to help facilitate themselves (Hmelo-Silver, Katic et al., 2007; Leary, Walker, Fitt, & Shelton, 2009). Indeed, Leary et al. (2009) have demonstrated that peer facilitation can lead to positive learning outcomes.

An example of technology used to support PBL can be found in the STELLAR project (Derry et al., 2006). Using STELLAR, Derry, Hmelo-Silver, and colleagues (2006) developed hybrid courses in educational psychology and the learning sciences for preservice teachers. The system included two major components:

1. The Knowledge Web (KWeb), a multimedia online resource that includes two integrated networks. One is the case library; a library of video cases representing teaching practices, and the second is a hypertext of conceptual knowledge from educational psychology.
2. PBL online: A site including scaffolding and tools to help groups carry out lesson design tasks. The tools included personal and collaborative workspaces, such as a group whiteboard (Figure 21.2) and threaded discussion.

The STELLAR environment provided preservice teachers with opportunities to engage with educational psychology concepts by using video cases as contexts for collaborative lesson design (Derry et al., 2006). STELLAR courses consist of three to four problem scenarios each lasting 2 to 3 weeks. A problem scenario includes both a video-case of a student or classroom as well as a problem statement that sets the students' goal to redesign the lesson or design a similar one, based on learning principles. These PBL modules present opportunities for discussion and (re)design of instruction based on video cases of classroom practice. The video cases were indexed to the KWeb, helping students identify fruitful learning issues.

The PBL online modules included tools that scaffold students' individual and group PBL activities (Collins, 2006; Hmelo-Silver, 2006). It broke the PBL process into 8 steps that guided students' collaborative problem solving (Dillenbourg, 2002) and directed them toward appropriate tools. These tools included a personal notebook to record initial observations; a threaded discussion, where students shared research; and a whiteboard where students posted and commented on proposals for lesson (re)designs. STELLAR embedded a domain-specific model of instructional planning in the tools (Wiggins & McTighe, 1998). For example, the whiteboard had separate tabs for identifying enduring understanding, evidence of understanding, and assessments. These same categories were used as prompts in the individual workspaces, communicating the instructional planning process with the intent of scaffolding the learners' activity throughout the PBL activity (Hmelo-Silver, 2006).

The second author has worked with preservice teachers in class sizes of 40 to 45 (De Simone, 2008, 2009). This is a large class for a group of novice PBL users. In this case, what made for an effective PBL implementation was initial modeling by an experienced PBL facilitator. We began the training by having preselected five high-performing students who the course instructor anticipated would readily engage in dialogue with one another as part of the PBL demonstration in front of the rest of the class. Then, as in the traditional PBL model, she presented students with a PBL problem and students generated learning issues, which were recorded on large sticky notes. Because of time restrictions, rather than having students pursue their inquiry, the facilitator served as their resource and helped students obtain the information needed to work through and analyze the problem. Because these students were new to PBL, the facilitator probed students with respect to educational psychology content and helped students with collaborative aspects of PBL inquiry. For example, she modeled how to summarize and check for understanding as well as how to record alternative points of view and consider all information before arriving at a conclusion. Finally, there was a period of self-reflection.

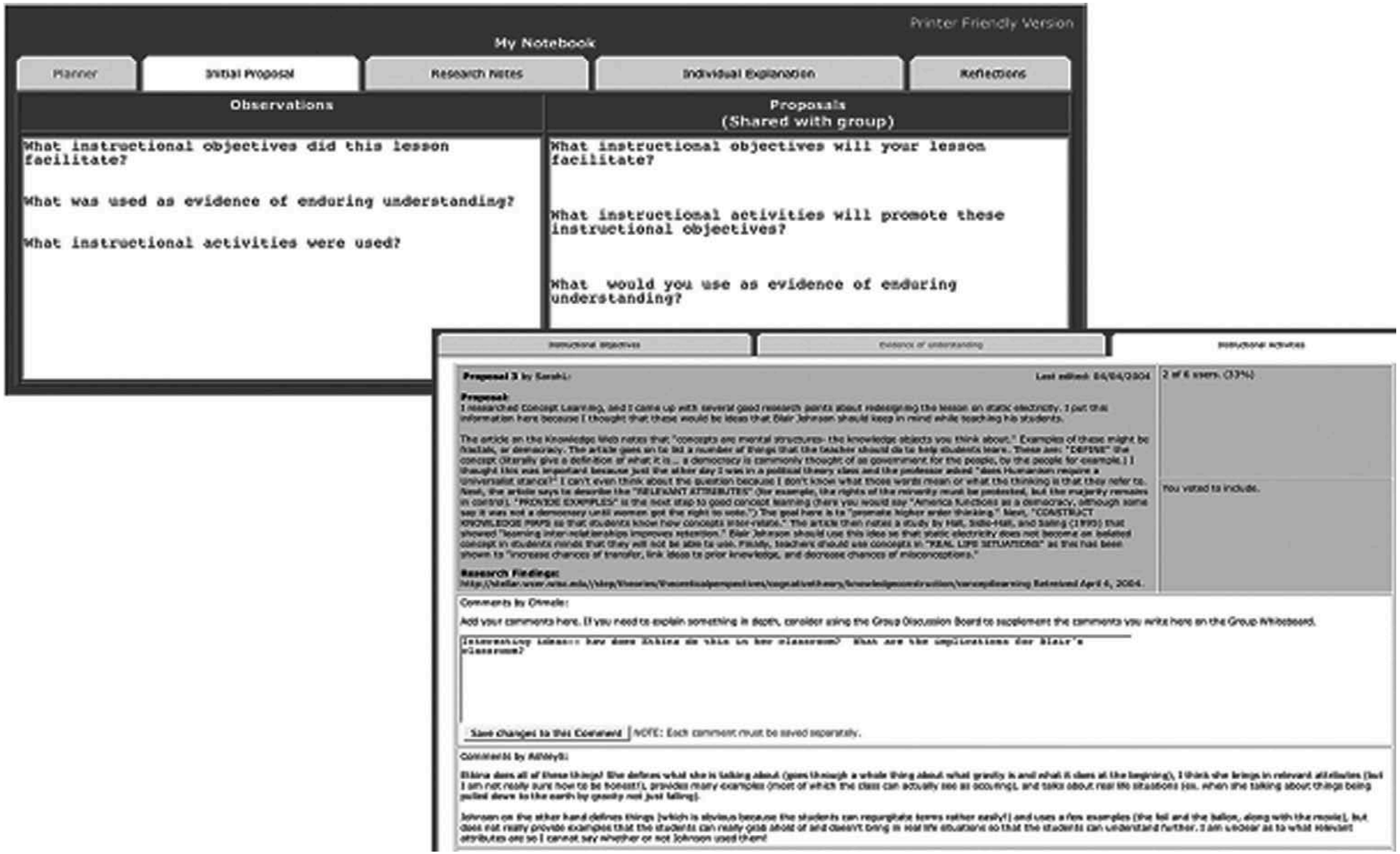

Figure 21.2 STELLAR Personal Notebook and Whiteboard

The facilitator probed group members' understanding of the PBL process and encouraged group members to ask further questions they might have about the content as it applied to the case. The rest of the class also had opportunities to ask questions about PBL process or content.

Subsequently, each newly trained person was assigned a small group where they modeled the PBL process. Expert facilitators rotated from group to group providing support and guidance as needed while students worked on a new problem. Groups were also given large sticky notes on which to write the facts and learning issues. Each group had a laptop computer to help with their SDL as well as a copy of their educational psychology text. Throughout the course process of helping students use PBL, the teacher conducted minilessons, which is a departure from the traditional model of PBL. Minilessons served the purpose of teaching a concept when the class as a whole needed the clarification or wanted to engage in a whole-class discussion. Conducting minilessons allowed students to listen to one another, discuss, and ask questions which could be shared with the rest of the class.

In addition, to foster collaboration among the PBL groups, the teacher provided group members with cue cards. Each cue card contained a question they could ask their group members in case they reached an impasse. The questions were guided by King's (1999) research on guided questioning. For example, one cue card asked a summarizing question such as "What are the main points so far?" Other cue cards presented a question that sought for clarification, such as "Can you provide me with another example?" "Would this be an example of what you are referring to?" and "I don't see how these two things relate? Can you explain it again?" Other recommended questions that picked up on a group member's idea, included: "Mike just said…what do we think about his idea given what is said in the case?" The purpose of these questions was to assist group members to probe one another's thinking by way of extending it. As group members became more comfortable asking each other questions, they were encouraged to further their dialogue by constructing their own probing questions that went beyond "yes" or "no" answers.

CONCLUSION

PBL is an approach to collaborative learning that situates learning in complex problems. It has been used for a range of grade levels and educational contexts. Although PBL uses complex problems as contexts for learning, there are a variety of supports for learning and collaboration that help students learn content, problem solving, and lifelong learning skills (Hmelo-Silver, Duncan, & Chinn, 2007). In addition to having a "groupworthy" problem, the facilitation helps keep the collaborative learning on track and supports productive collaboration. Representations such as the PBL whiteboard give the group a common focus for negotiation—it helps give the group a place to externalize their thinking and provides a concrete product for the group to jointly construct. We have illustrated two different adaptations of PBL in teacher education that provided additional supports for collaborative learning. Such supports include the use of technology-based scaffolding, peer facilitation, and just-in-time instruction. PBL can be challenging to manage because of large class size and varying levels of student commitment; it is nevertheless important to explore these adaptations to PBL as it is critical for these pedagogies to become adapted for all types of learners. Further research needs to examine how some of the instructional tools described elsewhere in this volume can support adaptation of PBL to the range of collaborative learning possibilities.

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