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Facilitating Problem-Based Learning

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> *…I want to find out … what is the depth of their understanding and I want them to recognize what they understand. But sometimes … 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….*
>
> (Hmelo-Silver & Barrows, 2015, p. 80)

We begin with a quote from Howard Barrows, a master facilitator, reflecting on his performance and on his role in facilitation. He viewed his role as helping the students recognize their understanding, putting ideas together, and, when necessary, asking questions. In this brief excerpt, several key aspects of facilitating problem-based learning (PBL) come to the foreground. Facilitation is one of the central and complex aspects of PBL. Although it may often mistakenly be perceived as passive, especially when compared with didactic approaches, effective facilitation is central to the success of a PBL group's social processes and learning. In this chapter, we review the epistemology underlying PBL facilitation; the goals of PBL facilitation, which include promoting deep engagement, supporting shared regulation, and self-directed learning (SDL); and promoting productive group dynamics. Next, we review research on factors related to effective facilitation, including facilitator characteristics such as subject-matter expertise, social and cognitive congruence, and being a peer versus an instructor. We also review specific strategies that facilitators use and educational technologies that can be used to support facilitation.

Facilitation strategies are designed to help scaffold social knowledge construction, support group regulation, and maintain group dynamics. Often these take the form of open-ended questions and revoicing student ideas. As PBL moves into a technology- and information-rich era, special considerations are needed for facilitating PBL in technology-mediated environments. Blended learning

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approaches have seen rapid shifts in the physical environment of many PBL classrooms. When combined with online access and new virtual spaces, these approaches are reconfiguring the dynamics of synchronous face-to-face facilitation and online facilitator engagement during SDL. Asynchronous PBL utilizing online meeting platforms and virtual environments are providing new opportunities for extending skilled facilitation. Finally, this chapter will also consider issues related to professional development of facilitators in terms of both the preparation and mentoring of new facilitators, and ongoing professional development needs of experienced facilitators.

Epistemology of PBL Facilitation

In his seminal work on the knowledge base for teaching, Shulman (1987) opposed technical approaches and envisaged "teaching as comprehension and reasoning, as transformation and reflection" devising an epistemological stance toward educating as "sound reasoning" (p. 13). As PBL educators, we not only engage in sound reasoning through designing PBL curricula and facilitating PBL tutorials, but by the very act of engaging in these processes, we, too, declare a fundamental philosophical stance toward knowledge and learning. Similar to Shulman's concerns in the 1980s, debates surrounding knowledge and curriculum in the 2000s criticize the longstanding epistemic frameworks of foundationalism, instrumentalism, and pragmatism for their "excessive focus on an essentialist view of knowledge and its divisions and a neglect of the transitivity inherent in the development of knowledge within the disciplines" (Scott, 2014, p. 26). For PBL, this fundamental premise that disciplinary knowledge is inherently transitive, fluid, and dynamic permeates curriculum design. It is central to a facilitator's practice and to the ultimate goal of developing the dispositions of lifelong learners (Boud & Feletti, 1997). PBL curriculum designers, therefore, adopt Whitehill, Bridges, and Chan's (2013) position that:

> For those engaged in PBL, there is a general consensus that there is no stable "truth" to be uncovered but that truth and knowledge are evolving, contested and under constant re-construction.... Whilst guiding students through key disciplinary content, PBL educators also seek to provide students with ways of knowing not only in developing the skills to access knowledge but also in analyzing and synthesizing this knowledge so as to "manage" it. Rethinking our position on epistemology is, therefore, the first step in understanding PBL as a philosophy. (p. 3)

As a philosophy, curriculum design, and approach to classroom learning, PBL, therefore, provides scaffolds for learners to explore and understand the logic and fundamental precepts of their discipline (Lu, Bridges, & Hmelo-Silver, 2014). PBL facilitators model higher-order thinking and reasoning so as to foster an inquiry-oriented approach to learning (Savery, 2006). It is key for the PBL facilitator, therefore, to understand the cognitive and social principles of PBL as a situated approach to learning (Lave & Wenger, 1991) driven by both the

contextual authenticity of the problems and issues at hand and the social dimension of mentored learning with peers in groups (Bridges, Chan, & Hmelo-Silver, 2016). In taking a situated approach, "learners are given real-world tasks and the scaffolding they need to carry out such tasks" (Collins & Kapur, 2014, p. 117). As one of these scaffolds, the PBL facilitator supports an apprenticeship in thinking by acting as a mentor for students' reasoning processes. As the social and cognitive dimensions of learning become enmeshed in new understandings of the learning sciences (Nathan & Sawyer, 2014), the foundational epistemic principles of learning in PBL remain not only current, but, perhaps, even more cogent given new understandings of the relationship between knowledge and the curriculum. These epistemic principles are embodied in the facilitators' goals and strategies.

Goals of Facilitation

The facilitator role is critical to making PBL function well. By making key aspects of expertise visible, and situating learning in meaningful tasks, PBL exemplifies the cognitive apprenticeship model (Collins & Kapur, 2014). In PBL, the facilitator models expert strategies for learning and reasoning, rather than providing content. Facilitators scaffold student learning through modeling and coaching, primarily through the use of questioning strategies (Hmelo-Silver & Barrows, 2006, 2008). As students become more experienced in PBL, facilitators can progressively fade their scaffolding, with the hope being that the collaborative learning groups will take on much of the facilitation task. The facilitator helps move the students through the PBL tutorial cycle (Hmelo-Silver, 2004) by maintaining the agenda and monitoring group dynamics and shared regulation. This monitoring assures that all students are involved, and that the facilitator's discourse moves encourage them both to externalize their own thinking and to comment on each other's thinking (Hmelo-Silver & Barrows, 2008; Koschmann, Myers, Feltovich, & Barrows, 1994).

The PBL facilitator (a) guides the development of higher-order thinking skills by encouraging students to justify their reasoning, and (b) externalizes self-reflection by directing appropriate questions to individuals. The facilitator plays an important role in modeling the problem-solving and SDL skills needed for self-assessing one's reasoning and understanding. Although facilitators fade some of their scaffolding as the group gains experience with the PBL method, they continue to monitor the group, making moment-to-moment decisions about how best to facilitate the PBL process. The facilitator directly supports several of the goals of PBL. First, the facilitator models the problem-solving and SDL processes. This might occur as the facilitator encourages medical students to generate and evaluate hypotheses, modeling a hypothetico-deductive reasoning process. In an engineering design problem, the facilitator might organize strategies around an engineering design cycle (Kolodner et al., 2003; Puntambekar, 2015). Second, the facilitator helps students learn to collaborate effectively. An underlying assumption is that when facilitators support the collaborative learning process, students are better able to construct flexible knowledge. The facilitator helps students collaborate by eliciting multiple perspectives

(e.g., "Does everyone agree?"), creating opportunities for all group members to articulate their ideas, and helping support equitable participation in general (Ertmer & Glazewski, 2015). Third, the facilitator helps the group identify the limits of their understanding by pushing students to explain their thinking and define terms that might be used without understanding. When students are not able to explain further, the facilitator suggests that those might become learning issues for the group to research during SDL and then share, evaluate, and synthesize at ensuing tutorials. As well, the facilitator prompts reflections on the learning resources that are used, providing further support for one of the SDL goals.

Promoting Deep Engagement

An important role for the facilitator is to help promote deep engagement with the ideas and disciplinary forms of reasoning. In medicine, that is the hypothetico-deductive form of reasoning but it might be argumentation in other science contexts (e.g., Engle & Conant, 2002; Forman & Ford, 2014) or more case-based reasoning in design domains such as engineering (e.g., Kolodner et al., 2003; Puntambekar, 2015). By asking the right questions at the right time, the facilitator can encourage students to engage deeply with disciplinary practices and content (Hmelo-Silver & Barrows, 2008).

The adoption of a classroom culture that promotes disciplinary reasoning and the practice of appropriate thinking strategies such as presenting evidence can help students remain productively engaged in the problem. If students are continually pushed to make connections between claims and evidence and how they help reach learning goals, students will become more reflective (Ertmer & Glazewski, 2015). Reminding the students of the underlying or major question driving their work can also help students stay on track, as one challenge of group work is reminding themselves what their major goals are. Keeping students on track can also encourage students to remain engaged with the activity. Hmelo and Guzdial (1996) suggested that when facilitators push students to articulate what they've learned and what they need to know, either by asking directly or by supplying the student with structured checklists, diaries, or other types of record keeping, the students will develop metacognitive strategies that allow scaffolded support to be removed later. As Ertmer and Glazewski (2015) pointed out, some students are able to go through the motions of completing tasks in their PBL team without actually developing a deep understanding of the concepts they are presented with. By frequently checking in with students, questioning the reasoning of the group and of the individual, and pushing students' metacognitive abilities, facilitators can promote deep engagement with the content.

Supporting Shared Regulation and SDL

One of the challenges for facilitators is to support shared regulation and effective SDL processes within the group. In particular, helping the students recognize what they know, what they don't know, and what they need to learn, helps students develop metacognitive skills, set learning goals, and prepare for the information searching they will need to do as they later research their learning issues. Some of the questioning that facilitators engage in needs to help students identify learning issues and reflect on the effectiveness of their collaboration and

learning strategies. In addition, the facilitator needs to help students think about vetting the resources that they use in learning and the balance between facilitator guidance and student self-reliance in that regard (Dolmans, 2016). The facilitator supports this by encouraging students to discuss the resources they identified in their SDL phase and evaluate them as a group, promoting shared responsibility for SDL (Chng, Yew, & Schmidt, 2015). Facilitators may also need to initially provide guidance for critically identifying reliable resources and perhaps initially constraining the resources students use to a manageable and high-quality set that they might later open up more broadly (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006; Dolmans, 2016).

Promoting Productive Group Dynamics

An important part of the facilitator role, especially for less experienced groups is to help support productive group dynamics. This involves monitoring the group, helping to ensure that all group members are involved and that the important ideas don't get lost—especially when they come from lower-status members of a group. It can involve finding the balance between being completely nondirective and providing guidance with regards to the group dynamics and shared regulation (Järvelä & Hadwin, 2013; McCaughan, 2015; Savin-Baden, 2003). Savin-Baden (2003) argued that because of the need to be cohesive, the PBL group might better be considered a team. That cohesiveness might not arise without some of the support that the facilitator provides, in particular, encouraging the group to take an "interactional stance". An interactional stance refers to the notion that all group members should participate equally in the discussion as they are mutually engaged in building on each other's ideas, disagreeing when appropriate (in respectful and principled ways), sharing in regulating the group process, and attending to the contributions of other learners (Hmelo-Silver, 2004; Hmelo-Silver & Barrows, 2008; Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014). Nonetheless, one issue for facilitators in fostering productive group dynamics is that of group size. There is an inherent logic that, in a small-group setting, the facilitator is better able to gauge the level of understanding of individual learners than in mass lecture contexts and the original developers of PBL proposed that a PBL group "cannot function well beyond eight members" (Barrows, 1988, p. 43). In an empirical study, Lohman and Finkelstein (2000) examined the effect of group size in PBL on selected outcome measures by comparing three group sizes: small (three students), medium (six students), and large (nine students). The study recommended the use of medium size groups in face-to-face facilitated PBL due to increased levels of self-directedness and more favorable reactions toward the learning experience.

Characteristics of Effective Facilitators

Subject-Matter Expertise

Facilitators need to have expertise in facilitation strategies and at least a threshold level of content understanding to guide learners, that is, to better understand when to push students on content and the strategies to accomplish this, as well

as when to hold back and allow students to regulate themselves and their group. Dolmans, Janssen-Noordman, and Wolfhagen's (2006) study of 573 PBL tutorial groups found that students could discern differing levels of facilitator expertise and perceived tutors to be least effective when they do not stimulate active learning processes. These tutors tended also to adopt a teacher-centric approach to facilitation. Analysis of students' responses to the item *tips for tutors* were grouped into four categories of areas for tutor improvement: (a) adequate evaluation; (b) being overly directive; (c) being too passive; and (d) content expertise. So it is clear that for students, content expertise was an important concern. In an analysis of a PBL tutorial, Hmelo-Silver and Barrows (2006, 2008) found that content expertise was a factor in determining when to guide groups to consider particular learning issues or hypotheses as compared to making a decision to let an issue leave the table. A review by Schmidt and Moust (2000) suggested that facilitator content expertise was a factor in student achievement. A more recent review by Leary, Walker, Shelton, and Fitt (2013) is more equivocal on the relationship between facilitator content knowledge and student achievement, though facilitator training appears to relate to student achievement. Nonetheless, content knowledge may exert an indirect effect as the facilitators use their content knowledge to determine what facilitation moves to make and when to make them. A key message from these results is that the effects of subject-matter expertise are mixed but also that this expertise is used in a more nuanced way than in direct instruction, in terms of helping the facilitator know when to use particular facilitation moves, when to push the students to explain because of relevance to the problem at hand, and when to let things go.

Cognitive and Social Congruence

Other characteristics of effective tutors are cognitive and social congruence (Cornwall, 1979; Schmidt & Moust, 1995; Yew & Yong, 2014). Cognitive congruence refers to the ability to explain ideas in a way that the student can understand because the facilitator shares a similar knowledge or professional base, and is able to understand the student's point of reference. Further, this includes the ability to communicate clearly and scaffold learning (Yew & Yong, 2014). Social congruence refers to interpersonal qualities of the facilitator including their personality, being able to relate to students, motivate students, creating a productive learning environment, and being professional (Yew & Yong, 2014). Given the student-centered approach of PBL, it makes sense that social congruence has been found to significantly influence students' learning processes and outcomes in PBL classrooms (Chng, Yew, & Schmidt, 2011).

Peer Facilitators

Peers can serve as facilitators in some PBL environments as they have the social congruence necessary in supporting facilitation and likely possess cognitive congruence, although they may lack the content expertise of faculty tutors. Especially in undergraduate, graduate, or professional education, peer tutors can assist in

facilitating discussion and keeping discourse on track in one group, as a dedicated tutor, or several groups, as a floating tutor (Allen & White III, 2001). A meta-analysis of facilitator effectiveness suggested that peer tutors can be very effective, even when compared with faculty tutors (Walker & Leary, 2009). In a study of peer facilitators in an educational psychology course for preservice teachers, Hmelo-Silver, Katic, Nagarajan, and Chernobilsky (2007) found that these students effectively served as "soft leaders" who guided their groups gently, with humor and humility, but also helped maintain the group agenda and push their group-mates to explain their thinking. This research also showed that this facilitation function was sometimes distributed across multiple students. According to Duch (2001), there are several ways in which a peer or near-peer tutor can extend productivity. First, peers can serve as role models for group members who are inexperienced with PBL environments, and can help to encourage those who do not participate as much as others. Second, as many peer tutors have taken and excelled in the course for which they are tutoring, they can check for conceptual understanding. Third, peer tutors can make decisions about when to push students through understanding difficult content, and can act as gatekeepers for resources to lead students toward deeper understanding. This would require a greater understanding of PBL facilitation by the peer tutor, and would likely require some assistance by the teacher in the form of training. Hmelo-Silver (2000) provided just-in-time support with a set of prompt cards that provided strategies that could be used with different goals as well as example prompts, as shown in Figure 13.1. Lastly, the peer tutors can provide information about group progress to the teacher, and can give insight into what is working well and what is not.

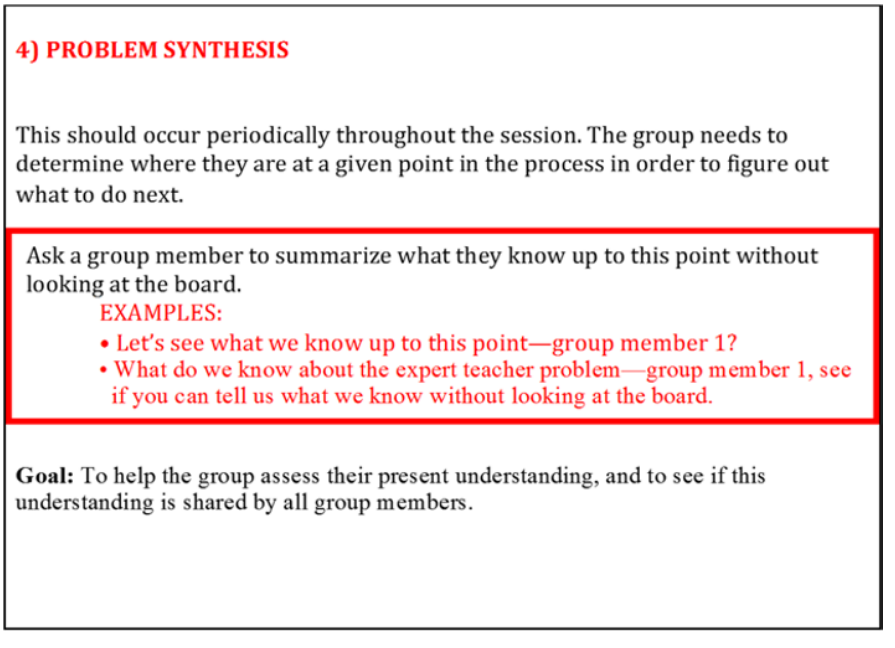

Figure 13.1 PBL Facilitator Prompt Card.

Facilitation Strategies

Facilitation is a subtle skill. It involves knowing when an appropriate question is called for, when the students are going off-track, and when the PBL process is stalled. Additionally, it requires knowing when to let students grapple with an idea versus when to suggest that the idea become a learning issue or to subtly guide them toward additional information or resources. These skills and strategies are applied both in-the-moment of a single tutorial and across the events of a full PBL cycle and require attending to accumulated consolidation across time. In a study of an expert PBL facilitator, Hmelo-Silver and Barrows (2006, 2008) found that he accomplished his role largely through metacognitive questioning and questioning that focused students' attention and elicited causal explanations. The facilitator used a variety of strategies to support his goal of getting medical students to construct causal models of a patient's illness. He asked students to explain their reasoning to the point where they realized that the limitations of their knowledge necessitated creating a learning issue. Another strategy was to ask students how hypotheses related to the patient's signs and symptoms in order to encourage the students to elaborate causal mechanisms. Finally, the facilitator also modeled reflection on his own performance. That research demonstrated that an expert facilitator has a flexible repertoire of strategies that can be tailored to different stages of the PBL process. Many of these strategies are designed to involve learners with disciplinary content.

As discussed earlier, strategies serve particular purposes as shown in Table 13.1. These include constructing explanations, promoting effective reasoning processes, helping learners become aware of the gaps in the knowledge and engaging learners in SDL. In addition to these educational goals, the facilitator also has performance goals, trying to ensure that all students are actively engaged in the learning process while also keeping the learning process on track, making their thinking visible, and scaffolding the groups in becoming increasingly self-regulated and reliant on themselves and others to address their learning needs.

Studying facilitation in a medical student group, Hmelo-Silver and Barrows (2006) identified several distinct strategies that facilitators used in a medical PBL setting, a subset of what is in Table 13.1. Some of these strategies may be widely useful, for example open-ended questioning (e.g., asking students to justify their reasoning) and revoicing. Revoicing involves repeating what students have said, perhaps rephrasing it to help the learners tune their language or refine their use of a concept. This can help in clarifying ideas as well as recognizing the contributions of the students who have contributed a particular idea. This is a strategy that is seen in many inquiry-oriented or dialogic approaches to learning (Resnick, Michaels, & O'Connor, 2010). Hmelo-Silver and Barrows (2006) provided examples of these strategies in action.

To generalize the work on facilitation, Zhang, Lundeberg, and Eberhardt (2011) used PBL for a summer professional development workshop, studying 6 groups with a total of 35 teachers. They found that experienced facilitators used a range of facilitation strategies "including questioning, revoicing, making connections, clarifying, reframing, summarizing, role playing, meta-talk, and modeling"

Table 13.1 Example Facilitation Strategies (from Hmelo-Silver & Barrows, 2006)

Strategy	Description	Purpose
1) Use of open-ended and metacognitive questioning	Wide range of questions that asked students to justify their thinking or that would ask students to engage in monitoring, evaluation, or reflection	General strategy to encourage explanations and recognition of knowledge limitations
2) Pushing for explanation	Use of what, why, and how questions; drawing flow chart	Construct causal models Help realize limits of their knowledge
3) Revoicing	Repeating what students have said, perhaps with slight rephrasing into more normative or disciplinary	Clarify ideas Legitimate ideas of low-status students Mark ideas as important and subtly influence direction of discussion
4) Summarizing	At slow points in discussion or when discussion is less focused, ask a student to summarize the group's current thinking	Ensure joint representation of problem Involve less vocal students Help students synthesize data Move group along in process Reveals facts that students think are important
5) Generate/evaluate hypotheses	Brainstorm ideas quickly and then focus inquiry based on evidence	Help students focus their inquiry Examine fit between hypotheses and accumulating evidence
6) Check consensus that whiteboard reflects discussion	Asking students if whiteboard reflects their discussion	Ensure all ideas get recorded and important ideas are not lost
7) Cleaning up the board	Have students focus on what is relevant and cross off ideas that might no longer be up for consideration	Evaluate ideas Maintain focus Keep process moving
8) Creating learning issues	When students can't define or explain, asking if that should be learning issue	Knowledge gaps as opportunities to learn
9) Encourage construction of visual representation	Suggesting students draw diagram, flow chart, concept map, etc.	Construct integrated knowledge structure that ties mechanisms to observable effects

(p. 342). They also found that the PBL facilitators provided encouragement, used humor to create a relaxing climate, and in general provided the kind of positive feedback needed to establish a learning community. Often these facilitation techniques are enacted through open-ended questioning.

Questioning

In order to move beyond the routine IRE (initiate, response, evaluate) structure of classroom discourse that is typically found in teacher-centered pedagogy, strategies that lead toward progressive transformative discourse need to be used (Hmelo-Silver & Barrows, 2008). The facilitator's use of questioning as a way to guide student learning is a powerful tool. Questioning can open or close a line of discourse, focus attention on certain content, activate prior knowledge, and assist in goal setting among other benefits (Burbules, 1993; see Hmelo-Silver & Barrows, 2008 for a description of questioning strategies). In essence, questioning is an important tool for facilitation and serves many purposes. Hmelo-Silver and Barrows (2008) found that the facilitator asked many types of questions. One type of simple question was a verification question such as "Are headaches associated with high blood pressure?" Such questions can serve to bring the group's attention to a particular kind of idea. More complex questions asked for definitions, examples, or causal relationships or mechanisms; for example, asking, "What do you guys know about compression leading to numbness and tingling?" A final kind of question tended to be task-oriented or meta-level questions that focused on group dynamics, monitoring, and SDL. For example, to check that the group was all on the same page, Barrows asked, "Megan, do you know what they are talking about?" Other questions in this category might include asking students what they wanted to do next or if an idea needed to be a learning issue.

Facilitation in Larger Classes

An important issue in moving beyond the traditional model of PBL that requires one facilitator to a group is one of scale. The role of the facilitator is extremely important in modeling thinking skills and providing metacognitive scaffolding. The medical school environment is privileged in being able to provide a facilitator for each small group. It is less clear how this might translate into other environments. Hmelo-Silver (2000) has successfully managed to facilitate multiple groups, using a *wandering* facilitation model. In this model, the facilitator rotates from group to group, adjusting the time spent with each of the groups in the classroom according to their needs. By looking at large poster sheets created by each group and hung on the classroom walls, she was able to dynamically assess the progress of each of the groups and adjust her facilitation efforts accordingly. In addition, students rotated through the facilitator role with the help of prompt cards that gave examples of different techniques that could be used at different stages of the PBL process (see Figure 13.1). This is a lower level of scaffolding than is possible in a one-facilitator-per-group model so some adaptations of PBL are needed to accomplish some of the facilitation functions. For example, reflection rarely happens in groups without a facilitator and so alternative mechanisms, such as structured journals, are needed to ensure reflection (Hmelo-Silver, 2000). This *wandering facilitation* strategy was used with undergraduate students, who are a more varied group than medical students but are still more mature than elementary and secondary students. Further

research is needed to explore strategies that can be used to facilitate PBL with less mature learners in a typical classroom of 25 or more students.

In another approach to managing a large class, Nicholl and Lou (2012) created a questioning guide that was used as a scaffold. Large classes (in the Nicoll and Lou example, 100 students) can be split into small teams of five or six. The instructor can answer questions and would hold large class discussions when multiple groups asked a similar question. In this way, students were asked to self-facilitate their groups as much as possible by following the guide provided by the instructor. The group members set ground rules, gave each other feedback at the end of each class and case, were able to assign jobs and learning issues to each member, and used the questioning guide that was designed to encourage accountability, critical thinking, and productive discussion. Feedback was collected from students for a period of 5 years, during which 92% of students reported that the facilitatorless format was beneficial and helped them develop their own facilitation skills. Thus, there are ways of using questioning in larger classes when the instructor cannot provide close guidance.

Facilitator Professional Development

We have argued in this chapter that facilitation is central to the PBL process and have noted that facilitator expertise and skills are viewed by students as key to success in terms of academic and social outcomes. Note that this section is focusing on faculty as facilitators rather than peers. The professional development of facilitators, therefore, is an additional aspect worthy of some consideration. This should be considered in terms of induction for skill development of new facilitators as well as in the provision of master classes for experienced facilitators to refine their craft. Quality assurance is also a critical link to both initial and ongoing facilitator development. In meeting these challenges in a case of large-scale implementation (over 100 PBL groups with 80 facilitators), Young and Papinczak (2013) identified strategies that were both organizational and specific to their professional development program:

- "Continual and needs-based professional development
- A return to Barrow's original vision of PBL facilitation
- Applying educational innovations from higher education
- Tutors using student feedback to improve practice." (pp. 826–827)

An induction program for new PBL facilitators needs to address the skills, strategies, and techniques of facilitation, and the underlying philosophical premises of the approach. For novices with a personal educational background and teaching experience rooted in didactic approaches, there may be both a conceptual and practical struggle to transition from role of teacher as "sage on the stage" to facilitator as "guide on the side." This change in role needs to be clearly linked to the fundamentally different view of content and knowledge in a PBL curriculum. This learning can be addressed through constructivist approaches but should remain central to professional development programs at all levels.

Faculty development program providers also now see a changing population in their programs. Some novice facilitators have themselves been educated through PBL programs and have an intimate understanding of facilitation and group processes. Interestingly, however, although facilitators may have experienced PBL as students, they may also lack an underlying conceptual understanding of the rationale for PBL or its design. Although experienced with the approach in the classroom, they are often surprised by the depth of curriculum planning and detail required in problem/case design and associated facilitator briefing and debriefing processes. This debriefing process is another important aspect of facilitator reflection that helps them learn to improve their facilitation skills and strategies. For fully integrated curriculum designs, novice facilitators should also be aware of the system-level matrix mapping of PBL learning issues and PBL problems/cases and their associated assessments across the years of a curriculum (Bridges, Yiu, & Botelho, 2016).

When focusing on PBL facilitator skill development, Salinitri, Wilhelm, and Crabtree's (2015) survey of programs indicated common approaches to include live or video-based observation of experienced facilitation with real students, various permutations of simulated facilitation through role play, and hybrid approaches combining information sessions and active engagement with the process. Their recommendation of constructivist designs utilizing technologies is both supportive of the PBL philosophy and draws on technologies to support the next-generation PBL. Other experiences with PBL faculty development indicate that engagement with dialogic processes is critical for facilitator development, particularly when also supporting curriculum reform processes in transitioning to a PBL curriculum design (Murray & Savin-Baden, 2000). Engaging facilitators in sustained dialogue begins in induction programs and includes the following central elements:

- active, practice-based approaches to facilitator skill development;
- reflective debriefings;
- sustained mentoring; and,
- programmatic peer review for quality assurance.

Like other forms of professional development for teachers, PBL facilitator training is a complex process that needs to be systematically designed and implemented. Another level of complexity is added when technology is added to the PBL mix.

Facilitating Technology-Supported PBL

Educational technologies can address longstanding issues regarding scaffolding student learning. Recent reviews of the use of technologies in PBL in health science education (Jin & Bridges, 2014) and more generally (Verstegen et al., 2016) indicate developments in this new iteration of PBL. Of the 28 included research studies between 1996 and 2014 in Jin and Bridges' (2014) systematic review, three types of educational technologies were found to have been adapted or specifically developed to support students in the PBL process of inquiry: (a) learning

software and digital learning objects (n = 20); (b) large screen visualizations such as interactive whiteboards (IWBs) and plasma screens (n = 5); and (c) learning management systems (LMS) (n = 3). The findings indicated emerging new forms of PBL in a "digital ecosystem" (p. 10). Five positive effects for student learning in technology-enhanced PBL were identified from these studies:

- providing rich, authentic problems and/or case contexts for learning;
- supporting student development of medical expertise through the accessing and structuring of expert knowledge and skills;
- making disciplinary thinking and strategies explicit;
- providing a platform to elicit articulation, collaboration, and reflection; and,
- reducing perceived cognitive load.

Technical support, infrastructure, and resources were found to be critical to successful uptake and implementation of PBL and these organizational issues are common across the wider educational technologies literature. Verstegen and colleagues' (2016) review across a wider range of educational contexts also indicated the centrality of technologies in supporting contextual and collaborative learning in PBL and noted the emergence of intelligent tutoring systems.

There are broadly two approaches to engaging with educational technologies that impact directly on facilitation. Facilitators may draw upon an array of educational technologies *infused within* the traditional, small-group, face-to-face process of inquiry into the PBL cycle (Bridges, Botelho, Green, & Chau, 2012). Alternatively, educational technologies may be drawn upon to *replace* traditional face-to-face PBL to adapt to distributed learning contexts such as supporting students on field placements (Ng, Bridges, Law, & Whitehill, 2013) or fostering internationalization initiatives (Hmelo-Silver et al., 2016). At the larger, curriculum level, educational technologies can scaffold PBL designs and processes. For example, devising PBL-oriented LMS and curriculum maps can support curriculum coherence (McLean & Murrell, 2002; Tedman, Alexander, & Loudon, 2007) and integration (Bridges, Yio, & Botelho, 2016) with potential for learning analytics to be generated for quality enhancement.

Using Technology to Directly Support Facilitation

The increasing use of technology in PBL classrooms allows for great flexibility on the part of the teacher and the student. Teachers can more quickly and closely monitor student progress, and students are afforded opportunities to strengthen metacognitive processes and ask for more guidance when necessary. Learning management systems can also be instrumental in a PBL classroom, especially in asynchronous learning environments. Asynchronous PBL is often conducted in a threaded discussion format, which encourages replies to an idea; however, such threads often make it difficult for a facilitator to track the development of the discussion (Orrill, 2002). Students tend to make fewer posts, though they may be more reflective (Hmelo-Silver, Nagarajan, & Derry, 2006; Lan, Tsai, Yang, & Hung, 2012). These threaded discussions present challenges for PBL facilitators, because they have less opportunity to provide immediate feedback in the context (Hmelo-Silver & Derry, 2007). Other challenges include limited quality and quantity of

student participation (Guzdial, 1997; Hewitt, 2005), and off-track discussions (Dennen, 2005; Ellis, 2001). As in face-to-face PBL facilitation, these online discussions can be stimulated with tutor encouragement, revoicing, providing participation guidelines, and summarizing the discussion (Beaudin, 1999). Other effective approaches include responding to a majority of student posts, directing comments to specific individuals, and significant instructor participation (Tagg & Dickenson, 1995). However, all of these strategies are labor intensive, and depend upon a tutor's ability to understand what is happening in the PBL groups. The benefit of online systems is in the amount of data that they can make available for facilitators, but it can also be overwhelming (Hogaboam et al., 2016).

One way to make the data tractable is through the use of learning analytics and dashboards. Dashboards provide a way for teachers to quickly assess the progress their students are making, see student questions or feedback, and monitor the pace of the lesson. Dashboards are often customizable and enable the user to see only what they need to without being encumbered by too much information. But the design and use of dashboards can pose challenges to meet the needs of facilitators. In a study of asynchronous PBL, Hogaboam et al. (2016) found that facilitators focused on student *output* rather than on their *activity* as evidence of engagement and did not find the data visualizations easily interpretable. The latter finding was attributed to the data being displayed out of context. Research on using dashboards and learning analytics in PBL is still nascent and requires research on how facilitators use the data as well as professional development to help them interpret the visualizations.

Educational Technologies Infused Within and Across the Face-to-Face PBL Cycle

At the level of PBL as an instructional approach where facilitators work with students in small group inquiry, technologies can draw upon a range of affordances and modalities, which can be infused across the whole PBL cycle of inquiry. Given that PBL is situated within a social view of learning, technological tools have the potential to support the social dimension of learning for team-building and collective reasoning processes (Lu, Lajoie, & Wiseman, 2010), particularly when students are in the SDL phase of the PBL cycle (Bridges, 2015). Wikis and forums can also be useful for promoting and enhancing student interactions out of class as well as providing timely feedback (Spector et al., 2016).

Table 13.2 describes examples of additional strategies for facilitating with technologies (see also Verstegen et al., 2016). One expanded role in the PBL group is that of student scribe as technology manager, particularly if group notes are digital and linked to the large screen display for collaborative text construction (shared documents, concept maps, wikis, etc.) or archiving group notations on learning objects and sourced images such as X-rays or design documents. Large-screen hardware linked to the PBL student scribe's laptop can range from passive displays to interactive screens such as IWBs. Early research in this area has found IWBs to encourage more adaptive approaches to problem solving (Lu & Lajoie, 2008). A more recent adaption of technologies in PBL is the use of Bluetooth sharing tools such as Clickshare™ so that multiple group members' laptop screens

Table 13.2 Strategies for Facilitating Face-to-Face PBL with Technologies

Technology	Strategy
Large-screen visualizations	Ensure control of screen displays is in the hands of students (scribe and group) (Bridges et al., 2014)
	Manage online searching (text and multimedia) via the scribe for: • real-time sharing to support group critique of sources (Jin, Bridges, Botelho, & Chan, 2015) • supporting students' structuring and framework building as real-time collaborative note making (such as with Google docs™) as part of the problem-based learning synthesis process (Lu et al., 2010)
	Invite a second "scribe" to take on "interactant role" with interactive screens to: • manipulate 3D inquiry objects (Yang, Zhang, & Bridges, 2012) annotate images and share with the group (Bridges et al., 2014) • make disciplinary thinking explicit using tools such as concept mapping software (Mok, Whitehill, & Dodd, 2014; Bridges, Corbet, and Chan, 2015)
In-class videos	Provide whole-group, synchronous viewing to support collective engagement and knowledge co-construction (Bridges, Corbet, and Chan, 2015)
	To activate prior and current knowledge during initial viewing in the first stage of the problem-based learning cycle, use the sequential disclosure approach to pause videos so students can identify facts and start hypothesizing
	For application and synthesis in the final stages of the problem-based learning cycle, replay the video for recapping and see if the group feels they have addressed the problems and issues at hand
Out-of-class videos	Ensure all students view prior to class meeting by sharing initial observations with group in class
Moderating wikis, forums, and other synchronous activities	Model good forum practices in class by having each group member log into and post to a wiki or forum issue in real time using a central display. This familiarizes students with the technology and allows in-class feedback and reflections on the quality of postings
	Make expectations for participation clear (e.g., frequency of posting, quality of responses, expectations for timeliness)

can be displayed via the central, large screen for group discussion. These adoptions of a variety of educational software within face-to-face facilitation using large-screen visualizations can support cognitive apprenticeship and induction into disciplinary reasoning processes.

PBL materials developers are also adopting multimodal resources to motivate and capture the interest of digitally adept students. New digital resources in medical education include the use of videos, 3D representations, virtual reality simulations, and, most recently, anatomy holograms. A major advantage of the inclusion of videos to replace or enhance PBL scenarios or cases is the ability to

enhance authenticity. One issue arising is the level of complexity provided by a video filmed in an authentic versus a simulated, role-played environment or paper-based scenario. Research has found that, while videos may change the amount of talk across different PBL phases, the quality of the discussion is at deeper levels with more time spent on problem identification (Chan, Lu, Ip, & Yip, 2012). Thus, they can support facilitation and promote the goals of facilitation, namely deep engagement and promoting productive group dynamics.

Educational Technologies to Replace Face-to-Face PBL

As PBL has evolved from its origins in medical education (Barrows, 2000), a new wave of curriculum designers and developers have sought to address issues of flexibility and scalability for improved student learning. One challenge for professional programs with community-based elements such as internships and study abroad opportunities has been how to maintain PBL group inquiry processes in distributed learning environments. Until recently, technologies have not been able to address the key concern of facilitating highly interactive exchanges in dynamic group environments, especially if using asynchronous models (Mattheos, Schittek, Attstrom, & Lyon, 2001). Ng et al. (2013) concluded that:

> online communication tools now support learning environments that afford increasingly reliable and stable one-to-one, one-to-many, and many-to-many text, audio and audio–visual interactions in real time and that by including multimedia search engines and databases, hypertext and various synchronous collaborative activities, this framework constitutes a powerful suite of tools for using online PBL to leverage modern technologies in the curriculum. (p. 4)

Their pilot adoption of synchronous web meeting platforms was one novel approach to maintaining group interactions and supporting students' while off-campus. Ng and colleagues' (2013) 4-week experience using Adobe Connect™ as an online PBL tutorial platform found high student uptake while not losing any academic gains when compared to assignment results from face-to-face PBL. In comparison to face-to-face PBL, the facilitator perceived no differences in coordinating group discussion, although new activities included student sharing of files and student collaborations on a shared notes file, and even found "the flow of discussion seemed to run more smoothly, and the amount of intervention required by the tutor was reduced" (p. 8). Similarly, Lajoie et al. (2014) used video as a context for synchronous PBL on medical communications with a synchronous web conferencing platform to connect medical students across continents. As a proof-of-concept short-term study, the facilitators had to both support the PBL discussion, and deal with helping the students adapt to the technology, including time delays because of bandwidth limits in one of the sites.

As raised in the discussion of face-to-face facilitation earlier, feasibility of staffing and administering small PBL groups has been insurmountable for some programs. Innovative online solutions seek to address the issue of scalability through simultaneous management by one online tutor of multiple groups

engaged in inquiry processes. For example, in the STELLAR project, Derry et al. (2006) used a mix of face-to-face and asynchronous interaction to help distribute some of the facilitation onto the learning environment and to allow a facilitator to interact with multiple groups. This system also allowed the course instructor to mentor less-experienced teaching assistants and provide advice as needed, which would be difficult in a face-to-face setting (Hmelo-Silver et al., 2006). An alternative to using web meeting platforms has been to conduct PBL in immersive virtual reality environments such as SecondLife™ (Savin-Baden et al., 2011; Savin-Baden, Poulton, Beaumont, & Conradi, 2016). Health sciences facilitators identified that, despite requiring an initial phase of adjustment to the potential distractions of an immersive, avatar-based environment, there were positive effects on student decision making although of a different order to traditional views of PBL knowledge construction.

Conclusion

Facilitation is an integral aspect of PBL environments, and requires time, training, and commitment to learn on the part of the teacher. Although facilitation skills are subtle, there is growing empirical evidence that characteristics like social and cognitive congruence as well as content expertise play a pivotal role in promoting the deep engagement that leads to student learning. Here, we reviewed research on factors related to successfully facilitating PBL lessons, certain strategies that promote learning, educational technologies that support facilitation, and approaches to the professional development of facilitators.

Facilitator strategies aid scaffolding collaborative knowledge construction, supporting shared regulation, and maintaining group dynamics. The use of questioning as a strategy is especially relevant and is a possible avenue for continued research. Although there have been several types of questions identified as well as the roles that they may play in the classroom, there has been a lack of research into which types of questioning are most useful in certain situations like moving a group through a difficult concept or asking students to link evidence with inferences.

Professional development for teachers, such as workshops for both new and veteran facilitators, is necessary to learn and practice skills. This is even more the case when using technology to support PBL. Mentoring of newer teachers by teachers more experienced with PBL is an indispensable method of training as well.

As PBL classrooms are more immersed in technology, special considerations are needed for facilitation and managing blended learning environments that incorporate online access and virtual spaces. Technology can be used as a tool to assist the facilitator in monitoring student progress, watching for questions, and providing access to resources. Specific types of technologies like dashboards, LMS, and IWBs (smartboards) have been especially useful as stimuli and scaffolds in PBL environments.

We conclude with the importance of reflection in facilitation. A good facilitator will demonstrate how they can be constructive in improving their own

performance for students, but they will also engage in being a reflective practitioner through discussions with colleagues and curriculum designers so as to continually improve their own practice as well as the wider implementation of PBL at their institution.

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