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In problem-based learning, students working in collaborative groups learn by resolving complex, realistic problems under the guidance of faculty. In this chapter, we examine the evidence for effectiveness of the method to achieve its goals of fostering deep understandings of content and discuss the potential for developing process skills: research, negotiation and teamwork, writing, and verbal communication.

Problem-Based Learning

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Problem-based learning (PBL) has wide currency on many college and university campuses, including our own, the University of Delaware. Although we would like to be able to claim clear evidence for PBL in terms of student learning outcomes, based on our review of the literature, we cannot state that research strongly favors a PBL approach, at least not if the primary evidence is subject matter learning.

There is some evidence of PBL effectiveness in medical school settings where it began, and there are numerous accounts of PBL implementation in various undergraduate contexts, replete with persuasively positive data from course evaluations (Duch, Groh, and Allen, 2001). However, evidence for learning outcomes is still needed. In this chapter, we review the origins of PBL, outline its characteristic methods, and suggest why we believe PBL has a persistent and growing influence among educators.

Origins of PBL in Medical Schools

PBL was formalized by medical educators in the 1950s and 1960s to address the exponential expansion of medical knowledge while better aligning traditional classroom problem-solving approaches with those used in clinical practice (Barrows and Tamblyn, 1980; Boud, 1985). Traditional approaches were based on the bucket theory (Wood, 1994): If medical students were filled with the requisite foundational knowledge, they would be able to strategically retrieve and direct just the right subsets of it toward problems of clinical practice. PBL was designed to address the underlying flaws of the bucket theory, especially leaky, overflowing, or inappropriately

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filled buckets. By presenting complex case histories typical of real patients as the pretext for learning, PBL demanded that students call on an integrated, multidisciplinary knowledge base (Wood, 1994).

In the idealized learning cycle of medical school PBL (Engle, 1999), students working in teams learn by solving real or realistic problems. Students grapple with a multistage, complex medical case history, which offers an engaging and memorable context for learning. As they define the problem's scope and boundaries, student teams identify and organize relevant ideas and prior knowledge. The teams form questions based on self-identified gaps in their knowledge, and they use these questions to guide subsequent independent research outside the classroom, with research tasks parceled out among team members. When the students reconvene, they present and discuss their findings, integrating their new knowledge and skills into the problem context. As they move through the stages of a complex problem, they continue to define new areas of needed learning in pursuit of a solution. In the case of this original PBL model, a solution is an accurate diagnosis and recommendation of successful treatment of the patient.

PBL continues to be a favored method in many medical schools. What became evident in effectiveness studies was that there was no simple answer to the question "Is PBL better than traditional methods?" Several meta-analyses of the data suggested that PBL has modest or no beneficial effect on student learning of content (from the United States Medical Licensing Examination [USMLE] Step 1—basic science understanding; Albanese and Mitchell, 1993; Nandi and others, 2000; Vernon and Blake, 1993). In fact, it appears that students in a traditional medical program sometimes, but not consistently, slightly outperform their PBL counterparts.

However, disaggregation of the data suggests an underlying richness that is not captured simply by looking at student achievement on content recall exams. If, for example, scores on the USMLE Step 2 (knowledge of clinical practice) or ability to apply knowledge in the clinic after graduation are considered, medical school students with PBL experience frequently outperform their traditional counterparts (Albanese and Mitchell, 1993; Dochy, Segers, Van den Bossche, and Gijbels, 2003; Koh, Khoo, Wong, and Koh, 2008; Vernon and Blake, 1993). Recent meta-analyses have begun to tease apart some of the relative merits of PBL and suggest that the most positive effects are seen with student understanding of the organizing principles that link concepts in the knowledge domain being studied (Gijbels, Dochy, Van den Bossche, and Segers, 2005). Dochy and others (2003) reported a robust positive effect from PBL on the skills of students, noting that, intriguingly, students in PBL remember more acquired knowledge compared with their traditional counterparts. The early meta-analyses of PBL outcomes in the medical school setting (Albanese and Mitchell, 1993; Vernon and Blake, 1993) also document positive student attitudes about learning, with students frequently viewing PBL as both a challenging and a motivating approach.

Strategies for PBL Implementation

Because PBL explicitly addresses some of the shortcomings of science education, it migrated into undergraduate science and engineering classrooms (Woods, 1985). It then expanded into basic as well as applied fields as well as into the humanities and social sciences (Duch and others, 2001). With the introduction of PBL to undergraduate courses, teachers modified the method to accommodate larger class sizes, greater student diversity, timing and scheduling issues, multiple classroom groups, and lack of suitable classroom space (Allen, Duch, and Groh, 1996).

PBL requires a shift in the educational paradigm for faculty. In PBL, the role of the instructor shifts from presenter of information to facilitator of a problem-solving process. Although the PBL process calls on students to become self-directed learners, faculty facilitators guide them by monitoring discussion and intervening when appropriate, asking questions that probe accuracy, relevance, and depth of information and analyses; raising new (or neglected) issues for consideration; and fostering full and even participation (Mayo, Donnelly, and Schwartz, 1995).

Instead of lecturing, PBL instructors must find or create good problems based on clear learning goals. Through these problems, instructors lead students to learn key concepts, facts, and processes related to core course content. PBL problems must be carefully constructed—not only to present students with issues and dilemmas that matter to them but also to foster their development of conceptual frameworks (Hung, Jonassen, and Liu, 2007). PBL problems may intentionally pose cognitive challenges by not providing all the information needed, thereby motivating a self-directed search for explanations. Instructors often allow students considerable latitude to make false starts and wrong turns. Well-developed, peer-reviewed problems can be found at the PBL Clearinghouse (University of Delaware, 2010).

Successful implementation of PBL is critically dependent on the instructor's scaffolding of students' active learning and knowledge construction (Amador, Miles, and Peters, 2006; Duch and others, 2001). For example, PBL instructors can plan for intervals of class discussion or minilectures to help students navigate conceptual impasses, to dig more deeply into certain topics, or to find useful resources. Instructors can enter team discussions to listen and pose questions (Hmelo-Silver, Duncan, and Chinn, 2007). They can also use student facilitators to extend their instructional reach.

Importantly, PBL can support the development of a range of "soft" skills: research skills, negotiation and teamwork, reading, writing, and oral communication. Cooperative learning strategies that foster effective teamwork become critical, as does the need for everyone to work to keep team members engaged and on track (Johnson, Johnson, and Smith, 1998). PBL classrooms are particularly well suited to the development of writing abilities. PBL instructors tend to rely on authentic assessment, with most problems leading up to a demonstration or presentation of learning, often taking the form of a written product: a solution, a recommendation, a summary of what was learned, or some other form of group or individual reporting. To encourage development of writing skills, thinking skills, and learning in general, instructors can call for students to produce specific genres of writing: progress reports, schedules, task lists, meeting minutes, abstracts, literature reviews, proofs, lab reports, data analyses, and technical briefings (Klein, 1999). Alaimo, Bean, Langenhan, and Nichols (2009) showed how to integrate writing as a core activity in an inquiry-based chemistry course, demonstrating strong learning outcomes in the process.

Instructors must also encourage good team communication strategies. Teams must avoid reaching premature closure or succumbing to groupthink—where a group seizes on a path because a team member is forceful or persuasive. The teams that perform best are those that generate and sustain consideration of multiple alternatives, engaging in and sustaining "substantive conflict" (Burnett, 1991).

Effectiveness of PBL on Content Learning in Undergraduate Settings

Confusion and lack of specification about what PBL is as it is actually practiced in the classroom hampers analysis of the effect of PBL on the acquisition of content learning. In particular, PBL adopters in undergraduate settings, grappling with the difficulties of monitoring multiple classroom groups, hybridize the method in various ways to incorporate aspects of discussion and case study method teaching (Silverman and Welty, 1990). Instructors tend to insert highly choreographed segments of instructor-centered, whole-class discussions into the PBL cycle and to interpose PBL problems intermittently throughout the course schedule, blended with more traditional instruction (Duch and others, 2001). As Newman (2003) noted, this hybridization of PBL makes it "difficult to distinguish between different types of PBL and even to distinguish between PBL and other educational interventions" (p. 7).

Nevertheless, there are scattered reports of positive outcomes. In a study of over 6,500 students, Hake (1998) found that interactive engagement methods (broadly defined as heads-on, hands-on activities with immediate feedback) were strongly superior to lecture-centered instruction in improving performance on valid and reliable mechanics tests used to assess students' understanding of physics. Williams (2001) reported gains in the Force Concept Inventory for students in a PBL course that are consistent with the averages in other introductory physics courses that use interactive engagement methods. Palaez (2002) observed that students in a PBL biology course with an intensive writing component outperformed students in a course using traditional lecture-based instruction on exams that assessed conceptual understandings.

Although there is less research on undergraduate learning than in medical education, the data support the broad conclusion that PBL may show only modest benefits on recalled content knowledge, but it positively influences integration of new knowledge with existing knowledge. However, faculty members frequently adopt PBL to help students develop lifelong learning skills. These skills are exercised routinely in the natural course of the PBL learning cycle. Given these additional but divergent student learning goals, many faculty members are satisfied with student content learning that is similar or not significantly decreased when using PBL. At the very least, these findings assuage any residual concerns they or others may have that spending time on these ambitious process objectives undermines the learning of essential course content.

Effectiveness of PBL on Process Skills

Because PBL engages students in a range of soft skills, perhaps other positive learning outcomes can be claimed for the method. A case in point is the benefit of using cooperative learning groups on such general aspects of academic success as retention as well as on fostering positive student attitudes about learning (Springer, Stanne, and Donovan, 1999). Another is the use of writing-to-learn strategies in PBL. Incorporation of short, in-class writing assignments improves student performance on traditional concept and content-based exams (Butler, Phillmann, and Smart, 2001; Davidson and Pearce, 1990; Drabick, Weisberg, Paul, and Bubier, 2007; Stewart, Myers, and Culley, 2010).

There is some evidence that systemic and sustained use of PBL in the classroom fosters cognitive growth. Downing and others (2009) followed two parallel cohorts of students in degree programs, one taught with PBL, the other by traditional methods, and found greater gains in metacognitive skills in the PBL group. Tiwari, Lai, So, and Yurn (2006) similarly reported significant differences in the development of undergraduate nursing students' critical thinking dispositions in a PBL versus a lecture-based course, as determined by comparisons of pre- and posttest scores on the California Critical Thinking Disposition Inventory.

Effectiveness of PBL on Student Engagement

Widespread agreement is emerging that at the core of effective teaching are activities that engage students by challenging them academically and involving them intensely, within supportive environments that provide multiple opportunities for interactions with faculty, peers, and members of the surrounding community (Smith, Sheppard, Johnson, and Johnson, 2005). Because PBL uses an assortment of methods associated with student engagement—active, collaborative, student-centered, and self-directed learning focused on realistic problems and authentic assessments—we might expect that it would lead to increased student engagement. By requiring students to talk to each other and collaborate on projects important to their academic success, PBL addresses student alienation and failure to form social networks, major reasons for students dropping out of college (Tinto, 1994). Two systematic analyses of students' perceptions of the immediate and longer-term value and transferability of the reasoning and processing skills they developed during PBL courses (using the National Study of Student Engagement survey [NSSE] or a similarly designed instrument) in fact provide support for characterization of PBL as a pedagogy of engagement (Ahlfeldt, Mehta, and Sellnow, 2005; Murray and Summerlee, 2007).

An important aspect of engagement is students' ability to practice self-regulated or lifelong learning behaviors (Smith et al., 2005): the ability to define what to learn and to effectively use the time and resource management needed to learn it. Blumberg's (2000) review of the literature described numerous instances of documented gains in these areas that can be attributed to students' PBL experiences.

Incorporating writing tasks into PBL problems also shows promise for enhancing student engagement. Butler and others (2001) found that short, in-class microthemes increased positive motivation to attend class and increased student engagement. Additionally, Light (2001) found that writing increases the time students spend on a course, increases the extent to which they are intellectually challenged, and increases their level of interest. Confirming Light's findings are the very compelling data emerging from the NSSE (Gonyea, Anderson, Anson, and Paine, 2010). NSSE personnel worked with writing faculty to develop a special set of add-on questions concerning writing to the spring 2009 administration of NSSE. The data strongly supported writing as the single most important determinant of engaged, deep learning. When the independent variable is assigning meaning-constructing writing tasks, the NSSE data show moderate to strong effects on increased higher-order thinking, integrative learning, and reflective learning.

Conclusions

There is broad support for the conclusion that PBL methods enhance the affective domain of student learning, improve student performance on complex tasks, and foster better retention of knowledge. We would argue that more research is needed, research that is sensitive to the range of outcomes that we have discussed. For example, we would like to see additional research into the effects of PBL on student performance on state board examinations and on students' gains in problem-solving, critical thinking, motivation, and self-regulated learning. Another important area of future research would identify the particular PBL implementation methods that lead to improved outcomes.

PBL continues to enjoy popularity among a wide range of instructors across numerous disciplines at many institutions. Because PBL changes the nature of teaching and learning, many instructors embrace the method without clear, confirming evidence of its effectiveness. In essence, they like being freed to work within a different classroom model, one where students are active and in control of learning. They like their role as consultant or facilitator better than their previous role of lecturer. The PBL classroom is, after all, a place that is lively with controversy, debate, and peer-to-peer communication—providing both faculty and students with immediate and unmistakable evidence of their competencies and understandings of and about what matters.

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