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Problem-Based Learning

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ABSTRACT

Problem-based learning (PBL) is perhaps the most innovative instructional method conceived in the history of education. PBL was originally designed to respond to the criticism that traditional teaching and learning methods fail to prepare medical students for solving problems in clinical settings. Instead of requiring that students study content knowledge and then practice context-free problems, PBL embeds students' learning processes in real-life problems. After its successful implementation in various fields of medical education, PBL is now being implemented throughout higher education as well as in K–12 education. The purpose of this chapter is to inform researchers and practitioners about research findings and issues in PBL that may be used to inform future studies. In this chapter, we review PBL research from the past 30 years. We first describe the history of development and implementation of PBL in various educational settings and define the major characteristics of PBL. We then review the research on PBL. First, we examine the effectiveness of PBL in terms of student learning outcomes, including basic domain knowledge acquisition and applications, retention of content and problem-solving skills, higher order thinking, self-directed learning/life-long learning, and self-perception. Second, we look at implementation issues, such as tutoring issues, curriculum design issues, and use of technology. Finally, we provide recommendations for future research.

KEYWORDS

Curriculum design: A process of conceiving a plan to define a set of courses constituting an area of specialization that supports the specified learning goal.

Problem-based learning: An instructional method that initiates students' learning by creating a need to solve an authentic problem. During the problem-solving process, students construct content knowledge and develop problem-solving skills as well as self-directed learning skills while working toward a solution to the problem.

Problem solving: A process of understanding the discrepancy between current and goal states of a problem, generating and testing hypotheses for the

causes of the problem, devising solutions to the problem, and executing the solution to satisfy the goal state of the problem.

INTRODUCTION AND HISTORY

Problem-based learning (PBL) is perhaps the most innovative pedagogical method ever implemented in education. Its effectiveness in facilitating student problem-solving and self-directed learning skills has been widely reported in medical education (Barrows and Tamblyn, 1980; Schmidt, 1983). PBL has also become increasingly popular across disciplines in higher education and K–12 education settings (Barrows, 2000; Dochy et al., 2003; Gallagher et al., 1992; Hmelo-Silver, 2004; Hmelo et al., 2000; Torp and Sage, 2002; Williams and Hmelo, 1998). So, what is PBL? What are the theoretical bases for this instructional method? Why does it receive such attention from researchers and educators across disciplines and age levels? How does it work? And does it really work? We begin this chapter by introducing the origins of PBL and providing a brief history of PBL as background information, followed by a discussion of its conceptual assumptions. We then review research on the effectiveness of PBL and the various implementation issues emerging from PBL research over the past 30 years. Finally, we conclude the chapter with a series of proposed research issues in light of previous experience and empirical evidence from PBL research and implementation, as well as potential research topics for future studies.

Brief History of PBL

Problem-Based Learning in Medical Education

Problem-based learning was first developed in medical education in the 1950s. The development of PBL is generally credited to the work of medical educators at McMaster University in Canada in the 1970s. Around the same time, other medical schools in various countries, such as Michigan State University in the United States, Maastricht University in the Netherlands, and Newcastle University in Australia were also developing problem-based learning curricula (Barrows, 1996). PBL was conceived and implemented in response to

students' unsatisfactory clinical performance (Barrows, 1996; Barrows and Tamblyn, 1980) that resulted from an emphasis on memorization of fragmented biomedical knowledge in the traditional health science education. This emphasis was blamed for failing to equip students with clinical problem-solving and life-long learning skills (Albanese and Mitchell, 1993; Barrows, 1996).

In the 1980s, the wider spread of PBL in the United States was accelerated by the GPEP report (Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine) sponsored by the Association of American Medical Colleges (Muller, 1984). This report made recommendations for changes in medical education, such as promoting independent learning and problem solving, reducing lecture hours, reducing scheduled time, and evaluating the ability to learn independently (Barrows, 1996). These recommendations strongly supported the implementation of PBL in medical education. During this period of time, some medical schools also began to develop alternative, parallel problem-based curricula (e.g., the Primary Care Curriculum at the University of New Mexico, the New Pathways Program in Medical School of Harvard University) for a subset of their students (Aspy et al., 1993; Barrows, 1996). Later, a number of medical schools, such as the University of Hawaii, Harvard University, and the University of Sherbrooke in Canada, assumed the more arduous tasks of converting their entire curriculum to PBL. In the 1990s, many more medical schools, such as Southern Illinois University, Rush, Bowman Gray, and Tufts, adopted PBL as their primary instructional method (Aspy et al., 1993; Barrows, 1994). Since its first implementation several decades ago, PBL has become a prominent pedagogical method in medical schools and health-science-related programs throughout the world, including North America, the Netherlands, England, Germany, Australia, New Zealand, and India.

Problem-Based Learning Outside the Medical Field

Higher Education

The adoption of PBL in higher education outside of the medical field as well as K–12 settings gradually occurred throughout the 1990s. PBL has been applied globally in a variety of professional schools (Boud and Feletti, 1991; Gijsselaers et al., 1995; Wilkerson and Gijsselaers, 1996), such as architecture (Donaldson, 1989; Maitland, 1998), business administration (Merchand, 1995), chemical engineering (Woods, 1996), engineering studies (Cawley, 1989), law schools (Boud

and Feletti, 1991; Kurtz et al., 1990; Pletinckx and Segers, 2001), leadership education (Bridges and Hallinger, 1992, 1995, 1996; Cunningham and Cordeiro, 2003), nursing (Barnard et al., 2005; Higgins, 1994), social work (Bolzan and Heycox, 1998), and teacher education (Oberlander and Talbert-Johnson, 2004). Moreover, Moust et al. (2005) reported that PBL is also frequently integrated into a wider range of disciplines, such as biology (Szeberenyi, 2005), biochemistry (Osgood et al., 2005), calculus (Seltzer et al., 1996), chemistry (Barak and Dori, 2005), economics (Garland, 1995), geology (Smith and Hoersch, 1995), psychology (Reynolds, 1997), science courses (Allen et al., 1996), physics, art history, educational psychology, leadership education, criminal justice, nutrition and dietetics, and other domains of post-secondary education (Edens, 2000; Savin-Baden, 2000; Savin-Baden and Wilkie, 2004).

K–12 Education

In introducing PBL into K–12 education, Barrows and Kelson (1993) systematically developed PBL curricula and teacher-training programs for all high-school core subjects (see Illinois Math and Science Academy, <http://www.imsa.edu>). Since then, PBL has been promoted by a number of scholars and practitioners for use in basic education (Arends, 1997; Glasgow, 1997; Jones et al., 1997; Kain, 2003; Krynock and Robb, 1999; Savoie and Hughes, 1994; Stepien et al., 2000; Torp and Sage, 2002; Wiggins and McTighe, 1998). Various results of implementations of PBL in K–12 settings have been widely reported. First, PBL has been shown to be effective in conveying a variety of content areas—for example, mathematics (Cognition and Technology Group at Vanderbilt, 1993), science (Kolodner et al., 2003; Linn et al., 1999), literature (Jacobsen and Spiro, 1994), history (Wieseman and Cadwell, 2005), and microeconomics (Maxwell et al., 2005). Second, PBL has been implemented effectively in schools in urban, suburban, and rural communities (Delisle, 1997; Fogarty, 1997). Third, PBL can be used effectively in a wide variety of student populations—for example, gifted elementary-, middle-, and high-school students (Dods, 1997; Gallagher, 1997; Gallagher et al., 1995; Stepien and Gallagher, 1993; Stepien et al., 1993), as well as low-income students (Stepien and Gallagher, 1993).

Interest in PBL is increasing in higher education and K–12 education as evidenced by the widespread publication of books about PBL (such as Barrows, 2000; Duch et al., 2001; Evenson and Hmelo, 2000; Kain, 2003; Torp and Sage, 2002). As Internet servers concerned with PBL (see <http://interact.bton.ac.uk/pbl/>) reveal, many teachers around the world are

using PBL, and the numbers are expected to grow. An increasing number of PBL literature reviews (Albanese and Mitchell, 1993; Dochy et al., 2003; Gijbels et al., 2005; Hmelo-Silver, 2004; Newman, 2003; Smits et al., 2002; Van den Bossche et al., 2000; Vernon and Blake, 1993) and PBL conferences (e.g., PUCP, 2006) also reflect the popularity of PBL.

ASSUMPTIONS AND CHARACTERISTICS

Assumptions

A primary assumption of PBL is that when we “solve the many problems we face everyday, learning occurs” (Barrows and Tamblyn, 1980, p. 1). Although such a statement may appear self-evident, this assumption is countered by the public assumption that learning occurs only in formal education settings, so once we leave school we cease to learn. Proponents of PBL believe, as did Karl Popper (1994), that “Alles leben ist Problemlösen [all life is problem solving].” If all life is problem solving, then all life is replete with learning opportunities. As we shall explain later, the most consistent finding from PBL research is the superiority of PBL-trained learners in life-long learning.

In addition to the importance of life-long learning, PBL proponents assume the primacy of problems in learning; that is, learning is initiated by an authentic, ill-structured problem. In PBL classes, students encounter the problem before learning, which is countered by centuries of formal education practice, where students are expected to master content before they ever encounter a problem and attempt to apply the content. Learning in PBL is bounded by problems.

Problem-based learning is based on constructivist assumptions about learning, such as:

- Knowledge is individually constructed and socially co-constructed from interactions with the environment; knowledge cannot be transmitted.
- There are necessarily multiple perspectives related to every phenomenon.
- Meaning and thinking are distributed among the culture and community in which we exist and the tools that we use.
- Knowledge is anchored in and indexed by relevant contexts.

Concomitantly, PBL is underpinned by theories of situated learning, which assume that learning is most effective when it is embedded in authentic tasks that

are anchored in everyday contexts. In everyday and professional lives, people continuously solve ill-structured problems, those that have multiple or unknown goals, solution methods, and criteria for solving the problems. Because meaning is derived by learners from interactions with the contexts in which they are working or learning (ideas abstracted from contexts and presented as theories have little, if any, meaning to learners), knowledge that is anchored in specific contexts is more meaningful, more integrated, better retained, and more transferable. One reason for this phenomenon is the ontology that students use to represent their understanding (Jonassen, 2006). Knowledge constructed for solving problems results in epistemological (task-related procedural knowledge) and phenomenological (the world as we consciously experience it) knowledge types. These are richer, more meaningful and memorable representations.

In addition to supporting more meaning by anchoring learning in authentic problems, problems provide a purpose for learning. Without an intention to learn, which is provided by problems, meaningful learning seldom occurs. When studying course content, students who are unable to articulate a clear purpose or intention for learning seldom learn meaningfully. When knowledge is evaluated based on its similarity to an authority, students' epistemological development is retarded. They fail to understand or accommodate multiple perspectives and make no effort to construct their own culturally relevant understanding.

Characteristics of PBL

Problem-based learning is an instructional methodology; that is, it is an instructional solution to learning problems. The primary goal of PBL is to enhance learning by requiring learners to solve problems. It is a methodology with the following characteristics:

- It is problem focused, such that learners begin learning by addressing simulations of an authentic, ill-structured problem. The content and skills to be learned are organized around problems, rather than as a hierarchical list of topics, so a reciprocal relationship exists between knowledge and the problem. Knowledge building is stimulated by the problem and applied back to the problem.
- It is student centered, because faculty cannot dictate learning.
- It is self-directed, such that students individually and collaboratively assume responsibility for generating learning issues and processes through self-assessment and peer

assessment and access their own learning materials. Required assignments are rarely made.

- It is self-reflective, such that learners monitor their understanding and learn to adjust strategies for learning.
- Tutors are facilitators (not knowledge disseminators) who support and model reasoning processes, facilitate group processes and interpersonal dynamics, probe students' knowledge deeply, and never interject content or provide direct answers to questions.

The PBL learning process normally involves the following steps:

- Students in groups of five to eight encounter and reason through the problem. They attempt to define and bound the problem and set learning goals by identifying what they know already, what hypotheses or conjectures they can think of, what they need to learn to better understand the dimensions of the problem, and what learning activities are required and who will perform them.
- During self-directed study, individual students complete their learning assignments. They collect and study resources and prepare reports to the group.
- Students share their learning with the group and revisit the problem, generating additional hypotheses and rejecting others based on their learning.
- At the end of the learning period (usually one week), students summarize and integrate their learning.

In the following sections, we discuss PBL effectiveness and implementation issues from PBL research findings.

RESEARCH RESULTS

Throughout the past several decades, a vast body of research on various aspects of PBL has contributed to our knowledge of PBL. Although PBL has gained popularity in K–12 and higher education, the majority of PBL research continues to be conducted in the medical education field. Within that body of research, some issues, such as the effects of PBL on student performance, have received more attention than others. In the following sections, we will review PBL studies in two major research areas: student learning outcomes and implementation issues.

Learning Outcomes

Basic Domain Knowledge

Acquisition and Applications

Problem-based learning is often criticized for its emphasis on facilitating higher order thinking and problem-solving skills at the expense of lower level knowledge acquisition. This concern has been expressed not only by teachers (Angeli, 2002) but also by students (Dods, 1997; Lieux, 2001; Schultz-Ross and Kline, 1999). In some cases, the students believed that content was inadequately covered, even though they understood the content more thoroughly (Dods, 1997) and performed comparably to traditional students on assessments (Lieux, 2001).

Higher Education and K–12 Education

Compared to PBL research conducted within the medical field, empirical studies conducted in non-medical disciplines and K–12 settings are relatively scarce. Polanco et al. (2004) investigated the effect of PBL on engineering students' academic achievement. They found that, when compared to their counterparts, PBL curriculum significantly enhanced engineering students' performance on the Mechanics Baseline Test, in which the focus of the test was on understanding and application of the concepts rather than recall of factual knowledge. Also, to evaluate the validity of the criticism that PBL students tend to underperform on knowledge acquisition when being measured with standardized tests, Gallagher and Stepien (1996) embarked upon an investigation in which they devised a 65-item multiple-choice test intentionally imitating typical final exams on the topic of American studies. The results showed that no significant difference existed in the content acquisition between students who were in the PBL course and students who were in the non-PBL course; in fact, the PBL students' average gain was higher than the other three traditional classes.

Zumbach et al. (2004) also studied PBL effects on fourth graders in a German elementary school. They found no significant difference on domain knowledge acquisition between students who studied using PBL and traditional formats. Similar results were also found in student learning in a Quantity Food Production and Service course (Lieux, 2001) and diabetes-related learning among adolescents with diabetes (Schlundt et al., 1999). Yet, a significantly lower gain score in economic knowledge was found in PBL classes than in lecture- and discussion-based classes in high-school economics classes (Mergendoller et al., 2000).

Medical Fields

Research from medical education, on the other hand, provides a rich body of empirical evidence for evaluating the effectiveness of PBL. Blake et al. (2000) reported a very successful implementation of PBL curriculum at the University of Missouri–Columbia. They compared the performance of six classes of medical students from 1995 to 2000 on the U.S. Medical Licensing Examination (USMLE, formerly NBME). They found that the PBL classes performed substantially better on both basic science and clinical science than did the classes under a traditional curriculum. More encouragingly, the mean scores of the PBL classes (1998 and 1999) were significantly higher than their respective national mean scores, and the mean scores of the traditional classes were lower than national mean scores. Especially, the 1996 class (traditional curriculum) scored significantly lower than the national mean score. Also, as measured by key feature problems (KFPs), Doucet et al. (1998) found PBL students performed significantly better on applying knowledge in clinical reasoning than did the traditional students in a headache diagnosis and management course. Similarly, PBL students performed significantly better than their counterparts in their clerkships (Distlehorst et al., 2005) and in podiatric medicine (Finch, 1999). Schwartz et al. (1997) compared PBL and traditional medical students at the University of Kentucky and found that PBL students performed equally well or better on factual knowledge tests and significantly better on the application of the knowledge in an essay exam and a standardized patient exam than did lecture-based students. Also, Shelton and Smith (1998) reported a better pass rate for the PBL biomedical students than their counterparts in both year 1 and year 2 in an undergraduate analytic science theory class.

To summarize existing empirical studies being conducted on PBL, a number of meta-analyses have been conducted. Albanese and Mitchell (1993) examined research from 1972 to 1992, and Vernon and Blake (1993) examined research from 1970 to 1992. Both meta-analyses concluded that, in general, the PBL research findings were mixed. The two meta-analyses agreed that traditional curriculum students perform better on basic science knowledge acquisition, but PBL students perform better on clinical knowledge acquisition and reasoning. Moreover, their finding that PBL students' knowledge acquisition was not robust was confirmed by another meta-analysis of 43 PBL studies conducted 10 years later by Dochy et al. (2003); however, when comparing students' performance on progress tests under PBL and traditional curriculum, Verhoeven et al.'s (1998) findings only

partially agreed with the findings of Albanese and Mitchell and Vernon and Blake. They found that the traditional students obtained better scores on basic science, while PBL students performed better on social science; yet, to their surprise, the PBL students did not outperform traditional students on clinical science. Two other PBL literature reviews conducted by Berkson (1993) and Colliver (2000) did not agree with the two seminal meta-analyses and found no convincing evidence to support the superiority of PBL in the acquisition of either basic or clinical knowledge. Nevertheless, they concluded that PBL resulted in similar achievement as did traditional methods, which implied that PBL would not undermine students' acquisition of domain knowledge.

Even though there is consensus that PBL curricula result in better knowledge application and clinical reasoning skills but perform less well in basic or factual knowledge acquisition than traditional curriculum, McParland et al. (2004) demonstrated that undergraduate PBL psychiatry students significantly outperformed their counterparts in examinations, which consisted of multiple-choice questions. Equivalent performance on basic science knowledge acquisition (or USMLE step 1) and knowledge application and clinical reasoning (or USMLE step 2) between students learning under PBL curriculum and traditional curricula was reported in several studies (Alleyne et al., 2002; Antepohl and Herzig, 1999; Blue et al., 1998; Distlehorst et al., 2005; Prince et al., 2003; Tomczak, 1991; Verhoeven et al., 1998).

Retention of Content

With respect to students' retention of content, PBL research revealed an interesting tendency. In terms of short-term retention, either no difference was found between PBL and traditional students (Gallagher and Stepien, 1996) or PBL students recalled slightly less (Dochy et al., 2003); yet, PBL students consistently outperformed traditional students on long-term retention assessments (Dochy et al., 2003; Mårtenson et al., 1985; Tans et al., 1986, as cited in Norman and Schmidt, 1992). In reviewing the studies that investigated the effects of PBL over time, Norman and Schmidt (1992) found some interesting results in several studies. Tans and associates found that PBL students' recall was up to five times greater on the concepts studied than traditional students 6 months after the course was completed. The study by Mårtenson et al. (1985) showed that no difference was found in the short-term retention of the content between PBL students and traditional students; however, the PBL students' long-term retention rate (average 25 points out of 40) was 60% higher than that of traditional students

(average 16 points out of 40) 2 to 4-1/2 years after the course was completed. Also, the PBL students tended to remember more about principles, whereas the traditional students retained more rote-memorization types of knowledge. Similarly, Eisensteadt et al. (1990) discovered that PBL students retained less than traditional students in the immediate recall test. Nonetheless, their retention rate remained rather consistent 2 years later, while the traditional students' retention had declined significantly. Dochy et al.'s (2003) review of PBL studies also echoed Norman and Schmidt's observation. Norman and Schmidt (1992), therefore, concluded that PBL might not improve students' initial acquisition of knowledge; however, the deeper processing of information in PBL classes appears to foster better retention of knowledge over a longer period of time.

Problem-Solving Skills

Improving problem-solving skills is one of the essential promises of PBL. The results of PBL research by and large support this assumption. Gallagher et al. (1992) conducted an experiment using an interdisciplinary PBL course called Science, Society and Future (SSF) on gifted high-school students with a comparison group of high-school students. They found that PBL students showed a significant increase in the use of the problem-finding step from pretest to post-test, which was a critical problem-solving technique. In contrast, in the post-test, the comparison group tended to skip the problem-finding step and move directly from the fact-finding step to the implementation step. The result suggested that PBL is effective in fostering students' development of appropriate problem-solving processes and skills.

Moreover, PBL has shown a positive impact on students' abilities to apply basic science knowledge and transfer problem-solving skills in real-world professional or personal situations. Lohman and Finkelstein (1999) found that the first-year dental education students in a 10-month PBL program improved significantly in their near transfer of problem-solving skills by an average of 31.3%, and their far transfer of problem-solving skills increased by an average of 23.1%. Based on their data, they suggested that repeated exposure to PBL was the key for facilitating the development of problem-solving skills. Several studies have shown that PBL has very positive effects on students' transfer of problem-solving skills to workplaces; for example, Woods (1996) reported that employers praised McMaster University's PBL chemical engineering graduates' outstanding problem-solving skills and job performance. Compared to other new employ-

ees who typically required 1 to 1-1/2 years of on-the-job training to be able to solve problems independently, "[the PBL graduates] think for themselves and solve problems upon graduation" (Woods, 1996, p. 97). Kuhn's (1998) study also illustrated the rapid development of expertise of first-year PBL residents in the emergency room. A superior ability to synthesize basic knowledge and clinical experience (Patel et al., 1991), in addition to applying and transferring the knowledge and skills into the workplace, may explain why PBL students outperformed traditional students in NBME/USMLE Part 2 while PBL students seemingly possessed slightly less basic science knowledge than traditional students as shown in their performance in NBME/USMLE Part 1. Clinical reasoning and solving problems on the job require more than mere memorization of factual knowledge. Norman and Schmidt (1992) pointed out that no evidence exists to confirm PBL advantages in general problem-solving skills that are content free, which, again, supports the effectiveness of authentic, contextualized learning in PBL.

Higher Order Thinking

Higher order thinking is an important cognitive skill required for developing sophisticated problem-solving skills and executing complex ill-structured problem-solving processes. To be an effective problem solver, students need to possess analytical, critical thinking, and metacognitive skills. Articulating problem spaces requires analytical skills (Newell and Simon, 1972), evaluating information involves critical thinking skills, and reflecting on one's own problem-solving process requires metacognitive skills. Shepherd (1998) reported that fourth- and fifth-grade students gained a significantly greater increase in critical thinking skills measured by the Cornell Critical Thinking Test (CCTT) than did the comparison group after participating in a 9-week PBL course (the Probe Method). Schlundt et al. (1999) also observed an improvement of self-efficacy in insulin administration management, problem-solving skills, and flexibilities in choosing coping strategies to overcome the difficulty of dietary adherence among adolescent diabetic patients who received a 2-week PBL summer program. They concluded that, instead of just teaching the facts, the PBL course helped the patients rationalize the self-care guidelines and consider more alternatives to seek better solutions and strategies to cope with the difficult lifestyle. Furthermore, in a longitudinal study of the problem-solving performance of medical students using PBL and traditional methods, Hmelo (1998) observed that students' problem-solving skills and processes changed qualitatively over time. This change

was certainly influenced by the type of curriculum. The students in the PBL curriculum, she noted, generated more accurate hypotheses and coherent explanations for their hypotheses, used hypothesis-driven reasoning, and also were more likely to explain their hypotheses and findings with science concepts as compared to traditional students.

Self-Directed Learning/Life-Long Learning

The ultimate goal of PBL is to educate students to be self-directed, independent, life-long learners. Through actively executing problem-solving processes and observing tutors' modeling problem-solving, reasoning, and metacognitive processes, PBL students learn how to think and learn independently. Though their data did not support the superiority of PBL on knowledge or general problem-solving skills acquisition, Norman and Schmidt (1992) concluded that PBL appeared to enhance self-directed learning. This conclusion was supported by Woods' (1996) assessment of chemical engineering students' comfort level toward self-directed learning. Ryan (1993) also reported a significant increase in PBL students' perceptions of their abilities as self-directed learners at the end of the semester in a health-science-related course. Moreover, Blumberg and Michael (1992) used students' self-reports and library circulation statistics as measures of students' self-directed learning behaviors between a PBL class (partially teacher-directed) and a lecture-based class. They concurred that PBL promoted self-directed learning behaviors in students. Similar evidence was also found in a number of studies, such as those by Coulson and Osborne (1984), Dwyer (1993), Dolmans and Schmidt (1994), and van den Hurk et al. (1999).

The long-term effects of PBL on helping students develop self-directed/life-long learning skills and professional preparation was even more evident in other research results. Two studies revealed that PBL graduates rated themselves better prepared professionally than their counterparts in terms of interpersonal skills, cooperation skills, problem-solving skills, self-directed learning, information gathering, professional skills (e.g., running meetings), and the ability to work and plan efficiently and independently (Schmidt and van der Molen, 2001; Schmidt et al., 2006). Moreover, in Woods' (1996) study mentioned before, the PBL alumni and the employers who hired the PBL graduates gave highly positive comments regarding their self-directedness and independence in solving work-related problems and improving professional development. These studies provided strong evidence for the positive long-term effects of PBL on students' self-directed and life-long learning skills and attitudes.

Reflection is another essential element required for self-directed learning in PBL (Barrows and Myers, 1993). The reflective inquiry process used in the study by Chrispeels and Martin (1998) provided the students in an administrative credential program with a metacognitive framework. This reflective process helped the students become effective problem solvers by exercising higher order thinking skills to identify personal and organizational factors that constituted the administrative problems they faced in work settings.

Self-Perception and Confidence

From students' perspectives, the effects of PBL have been positively perceived. Numerous studies have shown that students consider PBL to be effective in promoting their learning in dealing with complex problems (Martin et al., 1998), enhancing their confidence in judging alternatives for solving problems (Dean, 1999), acquiring social studies content (Shepherd, 1998), enriching their learning of basic science information (Caplow et al., 1997), developing thinking and problem-solving skills (Lieux, 2001), improving interpersonal and professional skills (Schmidt and van der Molen, 2001; Schmidt et al., 2006), and advancing self-directed learning, higher level thinking, and enhancement of information management skills (Kaufman and Mann, 1996).

In summary, PBL research results overall have clearly demonstrated advantages of PBL for preparing students for real-world challenges. The emphasis of PBL curricula on application of domain knowledge, problem solving, higher order thinking, and self-directed learning skills equips students with professional and life-long learning habits of mind, which are indispensable qualities of successful professionals. Although PBL students' performance in basic domain knowledge acquisition has been slightly inferior to traditional students, the format of the tests and the time-delay effects (PBL students have been found to retain information much longer and better than traditional students) may justify this result. This speculation may suggest further research issues and merit empirical evidence to shed deeper insight on these aspects of PBL.

Implementation of PBL

Problem-based learning is considered by many researchers to be the most innovative instructional method to date. As indicted before, these beliefs are anchored in PBL's atypical instructional process and components. They include learning initiated by problems, self-directed learning, and collaborative learning

in small groups. These components, which are radically different from traditional instructional methods, inevitably produce a considerable impact on the dynamics between instructors and students, among students, and on instructors and students' roles and responsibilities during the course of PBL.

Student Roles, Tutor Roles, and Tutoring Issues

The students as well as instructors have encountered great challenges when transitioning from traditional instructional methods to PBL. These challenges might have evolved from students' as well as tutors' interpretations of self-directed learning. According to Mifflin and associates (Mifflin, 2004; Mifflin et al., 1999, 2000), self-directed learning in PBL could range from preorganized teaching, student-initiated and -selected but instructor-guided learning, to completely self-taught learning. This wide spectrum of interpreting self-directed learning could have contributed to the confusion or unsettled feeling for the students while defining their roles in PBL courses. Similar uncertainty also occurred with the tutors when assuming their roles in the students' learning process. In the following sections, we discuss the perceptions of students as well as tutors in terms of their roles in the PBL processes, as well as the tutoring factors that influence student learning.

Students' Transition from Traditional Methods to PBL

In PBL, the students become the initiators of their own learning, the inquirers and problem solvers during the learning process, and they are no longer passive information receivers. The students not only are required to redefine their roles in the learning process but must also retune their learning habits. Woods (1994, 1996) speculated that uncertainty about their grades was one possibility accounting for students' uneasiness about a new instructional method, resulting in some resistance to change and making the initial transition from traditional curriculum to PBL curriculum more difficult. Schmidt et al. (1992) reported that students need at least 6 months to adapt to this new instructional method. The concern about the sufficiency of content coverage also partially contributed to students' anxiety during PBL (Lieux, 2001; Schultz-Ross and Kline, 1999). Jost et al. (1997) examined students' discomfort levels with PBL in the initial stage of instruction by analyzing the students' journals, self-evaluations, and a survey. They found that the students' anxiety mainly resulted from their uncertainty about their roles and responsibilities in the course and how they would be evaluated. The difficulty of assuming a more active role with more responsibility in the learning process

also results from the students' "learned" definition of roles in traditional methods (Dean, 1999; Jost et al., 1997, p. 90). Similar observations were also reported in studies by Fiddler and Knoll (1995), Dabbagh et al. (2000), and Lieux (2001). Furthermore, as Mifflin and associates (1999, 2000) conjectured, the questionable presumption that adult learners are capable of conducting highly self-directed learning may also play a role in students' difficulties in transitioning to PBL.

Although the sense of discomfort and anxiety is common among students during the initial stage of PBL implementation, Schultz-Ross and Kline (1999) found that the students' discomfort and dissatisfaction levels decreased significantly by the end of a PBL forensic psychiatry course. They reported that some students expressed uneasiness during the initial transition stage of PBL curriculum. Nonetheless, once the students adjusted to PBL environments and realized the merits of PBL, their perceived comfort levels about the learning issues of testimony, liability, and competence improved significantly, as did their perceptions regarding the subject matter (forensic psychiatry) learned in the course. Dabbagh et al. (2000) confirmed Schultz-Ross and Kline's observation.

Tutors' Roles in PBL

Barrows (1992) asserted that the two major responsibilities of tutors in PBL are facilitating the students' development of thinking or reasoning skills that promote problem solving, metacognition, and critical thinking, as well as helping them to become independent and self-directed learners. As Maudsley (1999) stated, the effectiveness of tutors is essential to the success of PBL. Maudsley suggested that PBL provides an opportunity for educators to redefine the nature of learning and, in turn, reposition their roles in teaching from a knowledge/information transmitter to a learning/thinking process facilitator. This shift requires PBL tutors to undergo a fundamental reconceptualization of their educational roles. Research showed that, after having gone through this reconceptualization process, a conceptual shift similar to that of the students also occurred among tutors.

Based on their data, Donaldson and Caplow (1996) described the PBL tutor's precarious position as a *dilemma*. Their research on the role expectations of PBL tutors revealed two major dilemmas perceived by PBL tutors: the conceptualization of facilitator and the tensions that arise as tutors tried to redefine their role in PBL as compared to their previous role as medical teacher. Naturally, PBL tutors' adjustments and perhaps some discomfort about their new roles were inevitable and anticipated. Margetson (1998) argued that this paradigm shift in instructional strategy could be

threatening to teachers who need to maintain control of the learning environment and prefer passive students. In addition, teachers who conceive knowledge as a body of information that should be transmitted from the knowledgeable teacher to the unknowing student could also feel threatened by the PBL process; thus, Maudsley (1999) cautioned that the PBL tutor must balance a degree of participation in students' learning processes and refrain from the temptation to lecture. Aguiar (2000) conducted an exploratory qualitative case study that examined teachers' perceptions and experiences in their roles as PBL tutors. Five main themes emerged describing how tutors perceived their roles within PBL: (1) facilitating group work, (2) role modeling, (3) providing feedback, (4) imparting information, and (5) supporting students' professional development. Furthermore, Wilkerson and Hundert (1998) described the challenge of multiple roles experienced by PBL tutors and assigned the following names to the roles they identified in PBL tutors: information disseminator, evaluator, parent, professional consultant, confidant, learner, and mediator.

Cognitive Congruence and Active Involvement

Schmidt and Moust (1995) introduced the concept of *cognitive congruence* as a necessary characteristic of an effective PBL tutor. Cognitive congruence is communication skills defined as "the ability to express oneself in the language of the students, using the concepts they use and explaining things in ways easily grasped by students" (Schmidt and Moust, 1995, p. 709). The effective communication skills are a premise for the other components of effective tutoring. Moreover, the authenticity of tutors' interactions is exhibited in their ability to communicate with students informally while maintaining an empathetic attitude. In addition, effective tutors must be willing to be actively involved with students. In the study by Martin et al. (1998), over 75% of the students felt that the faculty involved in the PBL course were passive and believed that their learning experiences would have been better if the faculty had more actively supported the students. The students' perceptions of tutors' passive involvement may have resulted from the tutors' misinterpretation of self-directed learning as self-taught learning discussed earlier.

Modeling Metacognition Skills and Self-Directed Learning

Mayo et al. (1993) examined students' perceptions of tutor effectiveness in a PBL surgery clerkship, and their data indicated the importance of the tutor as a "metacognitive guide." As metacognitive guides, PBL tutors help promote students' development of clinical

reasoning skills through actively modeling this process for the students. While not giving the answers, the tutors model what questions an expert physician would ask in a clinical setting and guide students to formulate questions as expert physicians would. Similar results were also obtained in Wilkerson's (1995) examination of students' perceptions of effective tutors. The results of a similar study conducted by Donaldson and Caplow (1996) echoed previous findings that effective tutors fell into three categories of role content: (1) facilitation expertise, (2) knowledge or cognitive expertise, and (3) clinical reasoning expertise. Students deemed tutors as effective and helpful when they encouraged students to critically evaluate the information gathered, questioned and probed the students' clinical reasoning processes, and, most importantly, allowed students to control the learning process. Questioning the students' clinical reasoning processes serves two functions: verifying the appropriateness of the students' reasoning and modeling expert physician's reasoning processes. Allowing self-control in the learning process is essential for students to develop self-directedness in their own learning.

Group Processing

Collaborative learning is another essential element of PBL. A study by Martin et al. (1998) indicated that collaborative group processing in PBL was identified as an enhancer for the students' metacognitive skills. Utilization of collaborative learning in instruction is theoretically sound; however, it may not be as straightforward as it sounds in practice. Achilles and Hoover (1996) pointed out a major concern in their study of implementing PBL at grades 6 to 12 that students had difficulty working in groups. The need for effective guidance of group processing was perceived not only by K-12 students but also by the medical students. When Mayo et al. (1993) examined tutor effectiveness in facilitating group processing, they found that tutor skills differed significantly. When 44 students evaluated 16 tutors using 12 characteristics determined to be essential to tutor effectiveness, the results revealed four consequential facilitation skills: (1) helping the group be aware of how group processing works, (2) encouraging feedback within the group, (3) guiding the group to set appropriate learning issues, and (4) assisting the group to integrate learning issues.

Similarly, De Grave et al. (1999) used the Tutor Intervention Profile (TIP) to assess the effectiveness of PBL tutors and found that mastering the enhancement of the learning process in the tutorial group was one of the characteristics that the students valued. Thus, researchers have suggested that the skills and

knowledge for creating productive collaboration relationships (Wilkerson, 1995) and an unthreatening working atmosphere (Schmidt and Moust, 1995) are critical. Furthermore, group size has also been found to be a factor that has potential effects on students' learning processes and outcomes. In studying the effects of group size on students' self-directedness, Lohman and Finkelstein (2000) found that the medium-sized group (six students) performed significantly better than the large group (nine students). Group processing is especially difficult when PBL is implemented in a large class. To address this issue, Shipman and Duch (2001) suggested that more structure of group processes is needed for facilitating large PBL classes. An interesting finding obtained by Elshafei (1998) was that, when students' higher level thinking in solving algebra problems was assessed, PBL did not show positive effects on students' performance when they were tested individually; yet, PBL appeared to be more effective when the students were tested in groups. This finding, whether PBL students' learning outcomes are collective or individual, seems worth pondering and pursuing further.

Expert Knowledge

The importance of expert knowledge is a relatively uncertain characteristic in facilitating group processing. When assessing the effectiveness of PBL tutors with TIP, De Grave et al. (1999) suggested that the occurrence of effective tutoring depended heavily on the use of expert knowledge. Also, Schmidt and Moust (1995) asserted that a suitable knowledge base with regard to the topic under study was imperative; yet, others (Davis et al., 1992; Silver and Wilkerson, 1991) have raised concerns that content experts tend to lecture and give explanations, which may undermine the intent of promoting students' self-directed learning. The majority of the research pertaining to this debate showed no significant differences in tutors' performance and students' perception about tutorial processes between content-experts and non-content-experts (Gilkison, 2003; Kaufman and Holmes, 1998; Regehr et al., 1995). Students generally rated expert tutors more effective than non-expert tutors, and in some of the studies (such as that by Eagle et al., 1992), students performed slightly better with expert tutors than with non-expert tutors. Yet, using students' perceptions and immediate learning outcomes as measures of effective tutoring could have masked what really happened; for example, Kaufman and Holmes (1998) observed that expert tutors have a more difficult time with the role of facilitator and tend to provide more explanations of case content. Similarly, Gilkison (2003) noted that the expert tutor initiated more topics

for discussion than the non-expert tutor (52% vs. 12.5%), and the non-expert tutor engaged more in facilitating group processes (55.9% vs. 38.5%) and less in directing learning (5.9% vs. 11.4%). These observations offered a plausible explanation for the expert tutors' better performance. Further examination of the interaction of expert and non-expert tutoring and students' development of self-directed learning skills would provide better insight on this issue. Also, the implications of these observations should be taken into account by PBL curriculum developers or designers when considering employing tutors who possess expert knowledge.

Assessment Issues

The assessment used in the early implementation of PBL largely relied on traditional U.S. board exams, which were standardized tests designed to assess students' factual knowledge (NBME step 1) and clinical reasoning (NBME step 2). Nendaz and Tekian (1999) criticized traditional assessment as not being in line with the principles of PBL; therefore, the PBL students' performance might have been at a disadvantage under traditional assessment. Fortunately, Blake et al. (2000) noted a shift in USMLE in more recent years such that the emphasis of assessment has moved from testing factual knowledge to assessing application of the knowledge. This change not only benefits the students who study under PBL curriculum but also signals an increasing attention to students' abilities to apply and transfer basic knowledge instead of focusing on factual knowledge acquisition. A number of different methodologies have been developed to assess students' problem-solving skills, reasoning skills, and personal progress; for example, according to the classification by Swanson et al. (1998), there are outcome-oriented instruments, such as the progress test (Van der Vleuten et al., 1996), essay exams, oral and structured oral examinations, patient-management problems, clinical reasoning exercises (Wood et al., 2000), problem-analysis questions (Des Marchais et al., 1993), and standardized patient-based tests, as well as process-oriented instruments, such as the triple-jump-based exercises (Smith, 1993), Medical Independent Learning Exercise (MILE) (Feletti et al., 1984), the four-step assessment test (4SAT) (Zimitat and Miflin, 2003), formative assessment (Neufeld et al., 1989), and tutor, peer, and self-assessment.

As Savin-Baden (2004) contended, assessment is probably one of the most controversial issues in PBL because it is probably the most important indicator for validating its effectiveness. The mixed results of PBL students' learning outcomes discussed earlier might

have been largely due to incomparable assessment being used. In their meta-analysis of PBL research, Gijbels et al. (2005) found that the effects of PBL varied mostly depending on the focus of assessment instrument used. PBL had the most positive effects when the instrument focused on assessing the understanding of principles that link concepts. This may explain the pattern seen in PBL research that traditional students performed better in basic knowledge acquisition while PBL students did better in application of knowledge and clinical reasoning. Reviewing the assessment in the medical schools implementing PBL from 1966 to 1998, Nendaz and Tekian (1999) concluded that a lack of uniformity existed with regard to the assessment methodologies used in measuring PBL students' performance.

Curriculum Design in PBL

A distinct characteristic of PBL is that learning is initiated by presenting a problem rather than teaching the content. If so, what is instruction in PBL? To this question, Barrows (1996, p. 8) stated that: "The curricular linchpin in PBL ... is the collection of problems in any given course or curriculum with each problem designed to stimulate student learning in areas relevant to the curriculum." This collection of problems is designed to fulfill four educational objectives in PBL: (1) structuring of knowledge for use in clinical contexts, (2) developing an effective clinical reasoning process, (3) developing effective self-directed learning skills, and (4) increasing motivation for learning (Barrows, 1986, pp. 481–482). Based on these educational objectives, Barrows developed a taxonomy for classifying PBL curricula into six categories using two variables with three levels each. The two variables include the degrees of self-directedness and problem structuredness. He further defined the three levels of the variable of self-directedness as teacher-directed, student-directed, and partially student and teacher directed. The three levels of the variable of problem structuredness were defined as complete case, partial-problem simulation, and full-problem simulation (free inquiry). The combination of the two variables and three levels creates a categorization of PBL curriculum design, which includes lecture-based cases, case-based lectures, case method, modified case-based, problem-based, and closed-loop problem-based. The decision regarding which category of PBL design a given PBL curriculum should take should be based on the degree of the educational objectives that must be reached and the characteristics of learners.

In more recent developments of PBL curriculum design, students were gradually being included in the

curriculum design process to provide insights from students' perspectives. Chung and Chow (2004) reported that the students' workload and assessment methods designed in the curriculum were improved to better address students' capabilities and promoted learning when student representation was included in the curriculum design process. In medical schools, PBL curricula are usually designed by a team of faculty members and instructional designers; however, PBL in K–12 education and higher education, as Maxwell et al. (2001) indicated, is often adopted by a single teacher or implemented in a single course rather than as a departmental curriculum. It is much more challenging, therefore, for individual teachers to independently design PBL problems for their classes without resources and support from administration (Angeli, 2002). This may explain the considerably fewer implementations of PBL in K–12 and higher education settings than in medical-related fields.

Problem Design

Given that a PBL curriculum consists of a collection of problems, there is no doubt that the problems themselves are crucial to the success of PBL (Duch, 2001; Trafton and Midgett, 2001). Perrenet et al. (2000) contended that students' learning could be enhanced by manipulating the quality of PBL problems because they in fact could influence students' activation of prior knowledge, their group processing, self-directed learning (Gijbels and Schmidt, 1990), and generation of useful learning issues (Dolmans et al., 1993). Selecting and writing appropriate and effective PBL problems are very challenging and difficult tasks (Angeli, 2002); however, the issues of the effectiveness of problems and designing PBL problems have not been researched adequately.

Effectiveness of Problems

The effectiveness of problems determines the effectiveness of PBL curriculum. The quality of PBL problems affects not only various aspects of student learning but also academic achievement. Ineffective problems could, as Dolmans et al. (1993) argued, cause students difficulty in generating learning issues that the problem is designed to cover and hence lead to insufficient content knowledge acquisition. To elucidate the effectiveness of PBL problems used in medical education, four studies set out to investigate this issue, and they yielded very similar results. According to Dolmans et al. (1993), the effectiveness of problems is defined as the degree of correspondence between student-generated learning issues and faculty objectives. When assessing how accurately the students identified learning issues that were specified by the

faculty to a given problem, Coulson and Osborne (1984) found that on average students identified 24.0 learning issues out of 39.3 objectives (about 62%). Dolmans et al. (1993) analyzed the correspondence between the instructors' intended objectives and student-generated learning issues based on their interpretations of the PBL problems. They found that only 64% of intended content was identified in the student-generated learning issues. The degrees of correspondence between objectives specified by the faculty and the student-generated learning issues for the 12 problems ranged from 27.7 to 100%. Similarly, O'Neill (2000) reported a 62% correspondence rate between faculty objectives and student-generated learning issues. In the study by van Gessel et al. (2003), a 62% match between faculty and student objectives and learning issues was obtained. In these four studies, in addition to the student-generated learning issues that matched faculty objectives, irrelevant learning issues were generated by the students. These results showed that insufficient content coverage in PBL could in fact occur; hence, without assurance of the quality of problem or intended aims being met, the effects of PBL would be unpredictable and therefore questionable.

Problem Design Models and Principles

A number of researchers have discussed and provided suggestions and guidelines for designing PBL problems; for example, Duch (2001) suggested a process of five stages of writing PBL problems (choose a central idea, think of a real-world context for the concept, stage the problem to lead students' research, write a teacher's guide, and identify resources for students). Lee (1999) proposed a decision model for problem selection in which selection of the PBL problem is a function of learning objectives, prior knowledge, domain knowledge, problem structuredness and complexity, and time availability. Aiming at promoting higher order thinking, Weiss (2003) suggested several principles for designing PBL problems, including considering students' prior knowledge, using ill-structured and authentic problems, and promoting collaborative, life-long, and self-directed learning. Stinson and Milner (1996) also offered design guidelines that PBL problems should be holistic, ill-structured, and contemporary and should mirror professional practice. A step-by-step PBL problem development cycle was proposed by Drummond-Young and Mohide (2001). This eight-step design process was designed specifically for nursing education and includes the following steps: (1) review expected learning outcomes, (2) determine content, (3) select a priority health issue and develop the problem, (4) develop supplementary material, (5) seek

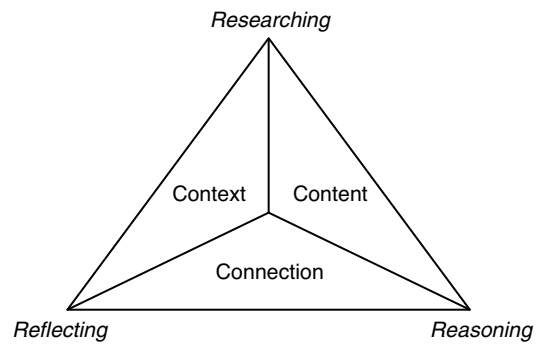


Figure 38.1 The 3C3R problem-based learning (PBL) problem design model.

evaluative feedback, (6) pilot the problem, (7) revise and refine the problem, and (8) integrate the problem into the curriculum. These problem design guidelines, principles, and processes are very helpful yet overly general or excessively profession specific; therefore, they are inadequate for providing educators and practitioners with a complete conceptual framework and the systematic design process required for designing effective PBL problems for learners across disciplines and ages.

Compared to PBL research on student learning outcomes, tutor techniques, student perceptions, or group processing, research on PBL problem design is rather scarce and unsystematic. To provide PBL educators and practitioners with a systematic conceptual framework for designing effective and reliable PBL problems, Hung (2006a) introduced the 3C3R model as a conceptual framework for systematically designing optimal PBL problems. The 3C3R PBL problem design model is a systematic method specifically designed to guide instructional designers and educators to design effective PBL problems for all levels and across disciplines of learners by strengthening the characteristics of PBL and alleviating implementation issues revealed in previous research on PBL, such as dilemmas of depth vs. breadth of content and factual knowledge acquisition vs. problem-solving skills acquirement (Albanese and Mitchell, 1993; Gallagher and Stepien, 1996; Hung et al., 2003). The 3C3R model (see Figure 38.1) has two classes of components: core components and processing components. The core components—content, context, and connection—are primarily concerned with the issues of appropriateness and sufficiency of content knowledge, knowledge contextualization, and knowledge integration. The processing components—researching, reasoning, and reflecting—deal with students' acquisition of content knowledge and the development of problem-solving skills and self-directed learning skills.

Following the establishment of the 3C3R model, Hung (2006b) further developed a nine-step problem design process to operationalize the conceptual framework into a step-by-step process:

- Step 1. Set goals and objectives.
- Step 2. Conduct content/task analysis.
- Step 3. Analyze context specification.
- Step 4. Select/generate PBL problem.
- Step 5. Conduct PBL problem affordance analysis.
- Step 6. Conduct correspondence analysis.
- Step 7. Conduct calibration processes.
- Step 8. Construct reflection component.
- Step 9. Examine inter-supporting relationships of 3C3R components.

Use of Technology in PBL

The use of technology in PBL follows two major trajectories: distance learning and use of multimedia.

Distance Learning and PBL

Most commonly, PBL takes place in a small group with intensive face-to-face discussions among students with guidance from tutors. With the development of technology and increasing popularity of the Internet, more and more online or distributed PBL (dPBL, defined as the use of PBL in an online environment; Cameron et al., 1999) curricula have been experimented with or implemented in the subject areas of, for example, social economy (Björck, 2002), education (Orrill, 2002), and science (Kim et al., 2001). To support PBL implementation at the University of Delaware, a Web-based technology system was utilized to help instructors organize courses (syllabi, groups, projects, and student reports) and to facilitate electronic communication (discussion sessions and between instructors and students), as well as provide online resources in support of PBL course development, such as ingredients for writing problems, inspiration for problem design, and information for solving problems (Watson, 2002).

In studying the effects of Internet technology on students' learning in PBL, Reznich and Werner (2001) observed a general positive effect, especially on the discussion process, in which the tutors played an important role in ensuring the success of the group sessions and guiding students to use electronic resources. In reviewing the literature of online PBL, we found that better access and retrieval of information are the main advantages of online PBL (Helokunnas and Herrala, 2001; Reznich and Werner, 2001; Watson, 2002); however, online environments seemed to fail to deliver the promise of fostering

collaborative learning, which many online PBL advocates have claimed, due to unsophisticated and cumbersome technology (Barrows, 2002; Orrill, 2002).

Use of Multimedia in PBL

Utilizing multimedia in constructing PBL environments is also gaining more attention as technology advances. The promise of using multimedia to enhance PBL is based on the assumption that PBL should take place in an authentic context (Albion and Gibson, 1998) to help students encode specificity of information, which is one of the necessary conditions for learning to occur (Schmidt, 1983). Some researchers (such as Hoffman and Ritchie, 1997) have argued that paper or oral presentation of PBL problems does not provide sufficient contextual or environmental information to prepare students to be able to recognize salient visual, auditory, or nonverbal cues that are crucial in some professions (Bridges, 1992). This implicit contextual information, such as social conventions or phenomenon and cultural/cross-cultural issues (Conway et al., 2002; Yamada and Maskarinec, 2004) or locality (Hays and Gupta, 2003), is lost in most conventional paper- or oral-based problem cases. This argument was confirmed by a study by Kamin et al. (2001) of the effects of different modalities on students' critical thinking abilities in a PBL course. They presented two groups of students with a problem in text format or video format. The results revealed that the video group did not identify as much of the information given in the problem as the text group. This performance of the video group in fact better resembled real-life situations; however, the video group examined the information more critically than the text group, who tended to accept the face value of the information given in the problem. Also, the video group had more active group processing than their counterparts. Bowdish et al. (2003) reported an experiment with a prototype of VPBL (virtual PBL). The VPBL incorporated multiple modalities, including digital video, images, text, questions, and text boxes, to present problem scenarios and facilitate the PBL process. This VPBL environment allowed the learners to observe the patient-doctor conversations and the doctor's bedside manner, to examine a chief complaint (for example, listening to heart and lung sounds), and to order and view diagnostic studies. To their surprise, no significant difference was found in the students' Teaching and Learning Environment Questionnaire (TLEQ) and achievement scores between the text-based group and the VPBL group. Similarly, William et al. (1998) reported that no difference existed in achievement scores when comparing computer-based and paper PBL with seventh graders in learning science concepts. Another case of using

multimedia in PBL to promote situated learning was reported by Zumbach et al. (2004). Their results also showed no significant differences in elementary students' factual knowledge acquisition and problem-solving skills under the multimedia-enhanced PBL or traditional class; however, the multimedia-enhanced PBL class showed a significantly higher level of motivation to learn as well as retention of knowledge than did the traditional class.

DIRECTIONS FOR FUTURE RESEARCH

As indicated earlier in this chapter, PBL is an instructional methodology. The PBL model calls for the construction of problem sets of authentic problems and the engagement of learning groups in negotiating learning issues to solve those problems. Although PBL has been shown to be successful in supporting deep levels of understanding, problem-solving skills, and lifelong learning, PBL research should pay more attention to the nature of the problems being solved. The PBL methodology assumes that all problems are solved in the same way and can be learned in the same way. We believe that this is a questionable assumption.

Problem Types and PBL

Probably the most important research question is that of addressing the nature of problems that are amenable to PBL. PBL emerged in medical schools, where students learn to solve diagnosis–solution problems, which are moderately ill structured. The goal of diagnosis is to find the source of the physiological anomaly; however, numerous paths can lead to a diagnosis. In the treatment or management part of the process, the problem often becomes more ill structured because of multiple treatment options, patient beliefs and desires, insurance companies, and so on.

Problem-based learning has migrated in academic institutions to law schools, where students learn to construct arguments based on evidentiary reasoning, a complex form of rule-using problem. PBL is becoming increasingly popular in graduate business programs, where students primarily solve case analysis problems that are fairly ill structured. As PBL migrates to other academic programs, such as engineering, research must be focused on the nature of the problems being solved and how efficacious PBL methodologies are for those kinds of problems. Along the continuum from well-structured to ill-structured problems (Jonassen, 2000), which kinds of problems can be effectively supported using PBL? For example, can PBL be adapted to word problems in physics, despite the inau-

thentic nature of those problems? The kind of problem that engineers most commonly solve is the design problem, which typically tends to be the most complex and ill-structured kind of problem that can be solved. Given an initial statement of need, an infinite number of potential solutions exists. Can learners self-direct their ability to solve this kind of problem or is some form of studio course required to accommodate its complexity? What is the range of complexity and structuredness that can be effectively learned using PBL? When Jacobs et al. (2003) surveyed medical students with a questionnaire that was designed based on Jonassen's continuum of structuredness and complexity of problems, they found that students weighted problem structuredness more heavily than problem complexity, which indicated that students preferred some degree of structuredness to identify a solution more easily. Taking students' perceptions into account in addition to the nature of the subject matter, then, how well-structured or ill-structured can and should PBL problems be? This will require comparing successes and failures across domains.

Assuming that PBL is effective for a range of problems, a related question is whether the established PBL methodology is equally appropriate for all kinds of problems, or should the method be adapted to accommodate different kinds of problems? Jonassen (2004) has prescribed different models for designing learning environments for story problems, troubleshooting problems, and case-analysis problems. Models for additional kinds of problems (e.g., design, decision making) are under development, but we do not know how unique each model for each kind of problem will be. A number of instructional supports, such as case libraries, question ontologies, simulations, argumentation systems, and problem representation tools, may be effective across several kinds of problems. We simply do not know.

Internal Factors and PBL

Problem-based learning was originally developed for training medical students. In those contexts, educators assume that students are cognitively ready for solving ill-structured problems and engaging in self-directed learning. As more PBL efforts are being implemented in K–12 schools, because of human development issues, younger students may not be ready to solve complex and ill-structured problems and self-direct their own learning. The question of learner characteristics (e.g., developmental level, epistemological beliefs, cognitive controls, maturity, reading ability) related to PBL has not been significantly addressed. Moreover, developing problem solving and self-

directed learning skills is both a goal of the course of learning and at the same time a required ability to succeed in PBL classes. So, frustration or detrimental effects may be inevitable if the learners (younger students or even adult students) possess few problem-solving and self-directed learning skills when they begin a PBL course. How can we reconcile this circulative prerequisite and goal requirement in the PBL process?

Designing Distributed PBL

With the emergence of online learning initiatives, researchers are working to implement PBL in online environments (Tan and Hung, 2007). This trend raises numerous implementation issues. How faithfully can PBL methodologies be applied online? An important element in PBL group processing and collaborative learning is building a sense of learning community. Barrows (2002) and Orrill (2002) showed that collaboration suffered in online PBL environments. Clearly, there is a distinct difference between conventional face-to-face and online PBL in the degree of social presence, which is defined by two factors: intimacy and immediacy (Wiener and Mehrabian, 1968). Given current technology, a low degree of intimacy and immediacy is inherent in online environments; thus, how do learning groups collaborate effectively to negotiate meaning? How can tutors effectively nurture and guide learning online? How can we support self-directed learning online? What compromises, if any, are required to engage learners in PBL online? Although the e-learning movement is not conceptually driven and the technology has not been as sophisticated as promised, it appears to be inevitable enough that these become important questions.

Multimedia can have a strong impact on the effectiveness of PBL when studying subjects for whom the ability to detect signs, symptoms, or behaviors through visual, audio, or tactile senses is crucial for solving problems. Appropriate modality of presentation of the problem could play a significant role in enhancing students' problem-solving skills in their fields. When training students, such abilities are one of the focuses of PBL curricula. Text-based problems would either give away the cues or be unable to afford the learning objectives of developing self-directed problem-solving skills; however, based on research results to date, the use of multimedia has seemed to fail to produce such effects. Thus, we might ask: Is it that the tutors did not take advantage of the technology and practice the same tutoring techniques as they did with text-based problems? What kind of facilitation should be given to guide students to the critical contextual information presented in the problem?

These issues that have emerged from experiences in implementing PBL in the past, as well as in response to new technology developments in the present, challenge PBL researchers and practitioners yet provide opportunities for new insights to be discovered in the future. Only continuing research will provide intellectual and scientific support to inform and improve the practice of PBL as well as education in general.

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* Indicates a core reference.