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# Theory to reality: a few issues in implementing problem-based learning

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**Abstract** The success of an intervention depends not only upon its theoretical soundness, but also on proper implementation that reflects the guidelines derived from its theoretical conception. Debates surrounding the effectiveness of problem-based learning (PBL) have focused on its theoretical conception and students' learning outcomes, but implementation is seemingly absent from the picture. This paper attempts to describe what research evidence is needed to fill in this missing information and provide a clearer picture of PBL. The author examines current PBL implementation practices and identifies potentially confounding variables that may play a role in inconsistent or conflicting research results in PBL. For example, various models of PBL have been developed and implemented to afford the specific instructional needs of the institution or learner population. These PBL models are in fact quite different in terms of the nature of problem solving and the degrees of self-directed learning, which theoretically, should result in different types of learning outcomes. Without distinguishing the models used, the results of comparative PBL research could have been confounded. Furthermore, human factors are another set of confounding variables that could influence the students' learning processes and consequently affect PBL implementations and research results. To remedy these problems and reach PBL's full potential, as well as obtain a more accurate picture of PBL as an instructional method and its effects on students' learning, some fundamental changes are needed.

**Keywords** Problem-based learning · Implementation · Problem solving · Self-directed learning · Student learning

Despite its popularity in educational settings, problem-based learning (PBL) generates a great deal of skepticism and speculation among theorists. More than half a dozen meta-analyses and systematic reviews of PBL studies have been conducted to answer the question, Is PBL effective? (See, for example, Albanese and Mitchell 1993; Berkson 1993;

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Colliver 2000; Neville 2009; Norman and Schmidt 1992; Vernon and Blake 1993). These meta-analyses examined the effect of PBL on various aspects of students' learning outcomes, such as domain knowledge acquisition, problem solving skills, self-directed learning, group processing, and social and psychological soft skills. However, the results from the meta-analyses were not conclusive, even yet, conflicting.

More recently, Kirschner et al. (2006) brought this issue back to the surface by openly criticizing PBL as an ineffective instructional method because it ignores or contradicts human cognitive architecture and cognitive load principles. Hmelo-Silver et al. (2007) and Schmidt et al. (2007) countered the argument by presenting the related cognitive science principles and empirical evidence that support the soundness of PBLs theoretical foundation. Specifically, some researchers suggested that PBL may not be effective in all aspects of student learning, but is especially effective in certain aspects of student learning because of its instructional emphases and characteristics. For example, there has been a general agreement that PBL is effective in promoting students' problem solving skills (e.g., Albanese and Mitchell 1993; Dabbagh and Denisar 2005; Strobel and van Barneveld 2009). However, Koh et al.'s (2008) systematic review of the long-term effects of PBL indicated otherwise. Their study compiled 13 studies that surveyed medical school graduates' competence from 1 to 23 years after graduation, and the results showed a weak level of evidence supporting the claim that PBL promotes problem solving skills. This debate continues.

In pondering why PBL research persistently produced inconsistent or even conflicting results, it is noted that previous research efforts, including the works mentioned earlier, appeared to debate the two ends of the instructional process—the theoretical conception and students' learning outcomes—without discussing the processes, that is the implementation of PBL. Though a limited number of studies started to consider the effects of processes (e.g. Dabbagh and Williams-Blijd 2010), most existing research on the effectiveness of PBL is largely based on students' learning outcomes. When an instructional intervention is implemented with real students in real-world settings, rather than in controlled laboratory conditions, numerous uncontrollable known and unknown variables could potentially affect students' final learning outcomes. The assessment of students learning outcomes provides us with only an end-result depiction of the interactions of all the variables involved in the implementation process, as well as the interaction between the theoretical conception and the reality. Thus, attempting to resolve the debate about the effectiveness of PBL by examining only the end results (i.e., final test scores or board exams) without scrutinizing the process may portray only half of the picture. Examining the actual implementations may help illuminate how and why the end results were produced, and in turn, shed light on how to improve PBL practices to yield desired learning outcomes that are aligned with the theoretical promises of PBL.

This paper does not attempt to settle the debate but approaches the issue from a less discussed perspective: the implementation of PBL. In the following, I examine the issue by first providing a brief description of the PBL theoretical basis, assumption, and promise. In the second part of the paper, I discuss the reality of PBL by examining a number of systematic PBL implementation evaluations[1] and related PBL literature. That is, what

[1] These evaluations were conducted largely in a medical education context because a limited number of systematic or large-scale PBL curricula have been implemented in nonmedical higher education and K-12 settings (Ertmer and Simons 2006; Hmelo-Silver 2004). Therefore, the number of systematic PBL program evaluations conducted and published outside of the medical education field is limited. Nevertheless, these PBL program evaluations could provide useful implications to be applied across different education disciplines and levels.

actually occurred during the PBL implementation in real settings? How faithfully and precisely were the PBL implementations able to follow and reflect the conception of PBL? Were the assumptions of PBL true in reality? If the answers to these questions are negative, what could be the possible sources for the discrepancies? Lastly, I offer some possible long term solutions as to how these problems can be alleviated to minimize the gap between the theory and the reality of PBL practice, and ultimately enhance the effects of PBL.

## Brief discussion of theoretical basis, assumption, and promise

In his review of PBL research, Neville (2009) remarked that the field of medical education immediately embraced PBL, even before empirical evidence became available to support it. This phenomenon does not necessarily imply the suitability, effectiveness, or superiority of PBL. However, it does suggest that educational psychologists and educators agree that PBLs theoretical conception fits contemporary understanding of human learning and instructional theories, as well as the expectations and demands of workplaces.

Many PBL researchers have addressed the theoretical conception of PBL (see, for example, Barrows and Tamblyn 1980; Schmidt 1983; De Grave et al. 1996), contending that it is based on the information processing model, cognitive theories, and constructivist theories. Specific theoretical conceptions include connecting new information with prior knowledge and schema (Bartlett 1968), elaboration and construction of information learned (Cermak and Craik 1979; Stillings 1995), collaborative learning (Dillenbourg et al. 1996), and social negotiation and construction (Jonassen 1991, 1992). These concepts are aligned with contemporary learning theories, including cognitivism and constructivism. In PBL, these concepts are translated into a number of fundamental components, including (1) problem-driven learning, (2) self-directed learning, and (3) collaborative learning (Barrows 1996) (please note that these do not reflect a complete list of all fundamental components of PBL. Only the components that pertain to the discussion in the implementation section are discussed here). In the following, I will discuss these components in more detail.

In PBL, the students' learning is initiated and consequently driven by a need to solve an authentic, ill-structured, real-world problem. This need affords a motivational function in that students realize the relevance of the content knowledge to their future professional or personal context (Barrows 1996). Problem-driven instruction also could motivate students to learn the subject due to the human nature of curiosity and taking on challenges. Through the process of solving the problem, students are not only acquiring the domain knowledge but also constructing a case-based structure in the memory for effective retrievals of the knowledge in the future (Kolodner et al. 2003). Also, the problems used in PBL are ill-structured, rather than well-structured. According to Jonassen (1997), ill-structured problems are characterized as containing vaguely defined goal states, several unknown problem elements, multiple plausible solutions, and ambiguity about the concepts or principles needed to solve them, while well-structured problems possess well-defined goal states, prescriptive arrangement of concepts and principles used, and a single definite solution. In PBL, the use of ill-structured problems is to help students develop their ability to adaptively apply their knowledge to deal with complicated problem situations that are normally seen in real world settings (Wilkerson and Gijselaers 1996).

Self-directed learning is another critical component in PBL. The main role of the instructor in PBL is modeling expert-like problem solving and reasoning processes for the students, instead of disseminating the knowledge. By observing and emulating the facilitator's reasoning and problem solving processes and being required to solve the problem independently (with an appropriate amount of guidance from the facilitator), the students are practicing and developing their own self-directed learning skills and meta-cognitive skills (Dolmans and Schmidt 1994). Thus, the self-directed learning component in PBL helps students actively, rather than passively, develop specific problem solving skills such as identifying the information that is known and needs to be known to solve the problem, generating and testing hypotheses, and devising solutions (Hmelo-Silver 2004). Furthermore, the challenge of solving a problem also motivates students to take initiatives in the problem solving process, as well as the learning process.

Furthermore, collaborative learning is also one of the main components. In PBL, students work in small groups. As Vygotsky (1978) argued, an individual's knowledge is a function of social, cultural, and historical factors, as well as a result of interacting with other individuals within the environment. Thus, a small group working format infuses the social aspect into the students' learning (Hmelo-Silver 2004). Roschelle and Teasley (1995) also argued that when a group of individuals gather together to achieve a common goal, the effect of learning may be accelerated and amplified as a result of being motivated to achieve the goal and the potential scaffoldings taking place within the group. Through group discussion and working collaboratively, PBL students decide what the problem is and collectively generate learning issues/objectives for their self-directed learning. In addition, the social interaction of working in groups helps students exercise their collaboration, cooperation, interpersonal, and communication skills and familiarizes them with the culture of the profession. In summary, motivated by the challenge of solving authentic problems, students work collaboratively and engage in necessary cognitive processes that help them actively self-direct (as opposed to teacher-direct) their own construction, application, integration, and reflection on the intended content knowledge within the relevant context. Thus, it is safe to suggest that PBL is a conceptually sound instructional method. Yet, the theoretical conception of PBL is based on ideal, logical assumptions and conditions. How closely does the PBL implementation in real settings reflect its theoretical conception? In the following, these questions will be examined from PBL literature and a number of systematic evaluations of institutional PBL implementations.

## Implementation of PBL

In reality, implementation of PBL at both the course and curriculum levels requires facing a number of challenges that may infuse confounding variables into the process and skew the end results. When examining the PBL literature, it was found that some probable confounding variables may derive from how PBL is implemented, how the curriculum or problems are designed, and other "human factors." The effects of these factors are likely manifested in the PBL students' problem-driven, self-directed, and small group learning related behaviors or activities.

### Issues related to instructional design

#### *Models of PBL*

Barrows and Tamblyn (1980, p. 18) originally defined PBL as "the learning that results from the process of working toward the understanding or resolution of a problem. The problem is encountered first in the learning process and serves as a focus or stimulus for the application of problem solving or reasoning skills, as well as for the search for or study of information or knowledge needed to understand the mechanisms responsible for the problem and how it might be resolved," which we now refer to as "pure" PBL. However, when it is implemented in different educational settings, a number of factors necessitate varying some aspects of PBL to meet its specific instructional needs and constraints, for example, the level of self-directed learning. These factors could include the nature of the disciplines, the learning goals, and the cognitive readiness or self-directed learning skills of the students. As a result, many variations of PBL models are generated and practiced in educational settings (Kaufman 2000; Rothman 2000; Savery 2006). This flourishing development of PBL model variations has made PBL a flexible and robust pedagogical approach for affording different and unique instructional needs in specific contexts.

A number of researchers have attempted to classify the PBL models. Barrows (1986) proposed a taxonomy that classified PBL into six categories using two variables with three levels. The two variables are the degrees of self-directedness and problem structuredness. He further defined the three levels for the variable of self-directedness as (1) teacher-directed, (2) student-directed, and (3) partially student- and teacher-directed. For the variable of problem structuredness, he defined the three levels as (1) complete case, in which the problem is presented in complete format with an organized summary of facts, (2) full problem simulation (free inquiry), in which problems are ill-structured and presented with incomplete information, and (3) partial problem simulation, which lies between complete case and full problem simulation.

Hmelo-Silver (2004) also discussed three PBL instructional approaches (PBL, anchored instruction, and project-based sciences) in terms of their format and the tools used, such as the role of problems and the role of teachers. Furthermore, Harden and Davis (1998) devised a comprehensive categorization of 11 steps (or levels) of PBL models that fall into a spectrum of instructional approaches (ranging from theoretical learning to task-based learning) with different levels of problem-driven or lecture-driven instruction, as well as the order of teaching concepts and problems.

This wide spectrum of PBL model variations promotes the applicability of PBL. However, it might also be one of the confounding factors that accounts for conflicting results in PBL research. It has been noted that the line between problem-based learning and project-based learning is blurred in some researchers' writings (e.g., Blumenfeld et al. 1991). When the term "PBL" is used loosely by researchers and practitioners, the attempts to examine whether PBL is effective in certain aspects may be difficult. This is because the learning processes (e.g., content knowledge acquisition or problem solving reasoning) vary among these PBL models, which could result in varying cognitive demands and psychological engagement of the learners. Consequently, these varying degrees of cognitive demand and psychological engagement could produce different degrees of impact on various aspects of learning outcomes.

In the three categorizations of PBL instruction proposed by Barrows (1986), Hmelo-Silver (2004), and Harden and Davis' (1998), some PBL models appeared in all categorization systems while others were unique in their own categorization systems. For the purpose of analyzing different PBL models' impact on different aspects of student learning, Barrows' taxonomy can be used as a structural framework to synthesize the models discussed in the three categorization systems. Six representative PBL models (see Fig. 1) can be identified as a result: pure PBL, hybrid PBL, anchored instruction, project-based learning, case-based learning, and instruction with problem solving activities (e.g. problem as a test, example, or integrator, Duffy and Cunningham 1996). The distinctions in the impact on learning outcomes in these six PBL models become notable when they are

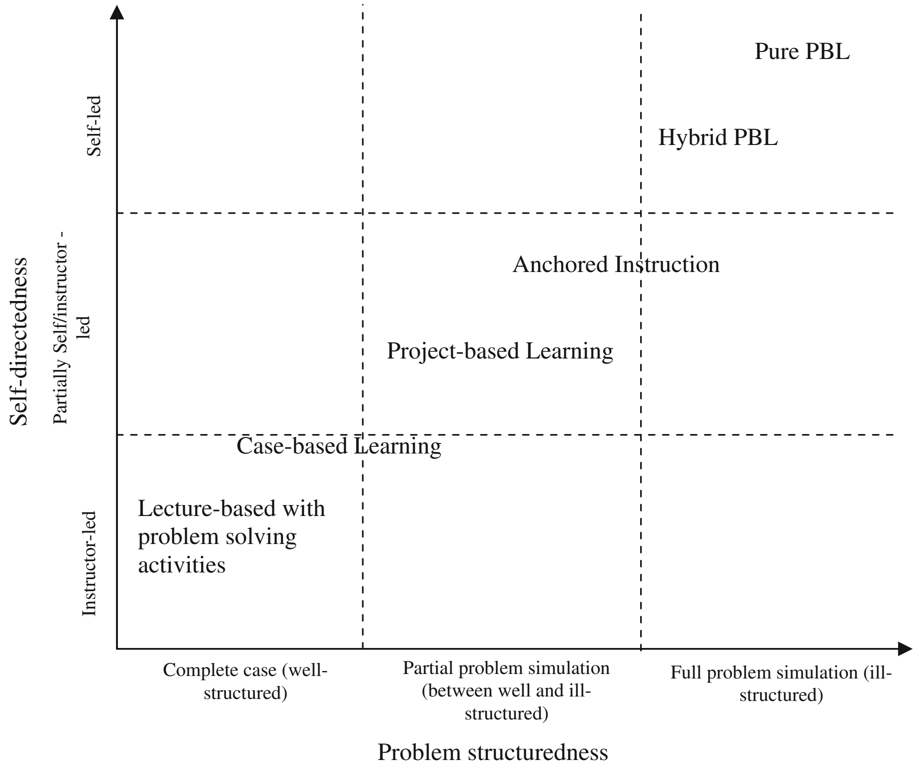


**Fig. 1** Six representative PBL models in Barrows' PBL taxonomy

analyzed with the cognitive processing requirements in terms of levels of self-directedness and problem structuredness (see Table 1). For example, the PBL model that requires learners to use a full degree of self-directed learning and solve highly ill-structured problems (e.g., pure PBL) is likely to result in better development of self-directed learning skills and the ability to deal with uncertainty than the PBL models that use partial instructor and student-led learning (e.g., project-based learning in which content is taught first, then students are assigned a project using the content, or anchored instruction in which the students' problem solving uses prior knowledge and the content knowledge is provided to the students when needed; Hmelo-Silver 2004).

By using this categorization system, the different models can be judged according to their degrees of self-directedness and problem structuredness as well as their effectiveness in different aspects of student learning. For example, PBL implementations that used project-based learning might not have produced a high impact on the students' self-directed learning skills. However, these PBL models could have helped students contextualize the content knowledge and hence promoted knowledge transfer. Moreover, the implementations that used the PBL models of case-based learning or instruction with problem solving activities could have produced even lower degrees of impact on the students' self-directed learning skills, problem solving/reasoning skills, and abilities to cope with uncertainty. This could have been due to the low degree of demand on the students to assume an active role in the problem solving and learning processes. Yet, these

**Table 1** Comparison of PBL models

| Models | Format | PBL processes | | | | | Problem characteristic | Impact on learning outcomes (theoretically) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Problem solving reasoning led by | Content knowledge acquisition | Timing of knowledge acquisition and application | Problem solving process is a | Content contextual-ization | Structuredness | Efficiency of content knowledge acquisition/coverage | Knowledge application and transfer | Problem solving and reasoning skills | Self-directed learning skill | Ability to cope with uncertainty |
| Pure PBL | Learning initiated by a need to solve a real world, ill-structured problem, no lectures | Learner | Learner self-acquired | Simultaneously | Inquiry process | Very high | Highly ill-structured | Medium to high | Very high | Very high | Very high | Very high |
| Hybrid PBL | Pure PBL supplemented with a few lectures | Learner- | Learner self-acquired with minimal assistance from the instructor on integration of content knowledge | Simultaneously | Inquiry process | Very high | Highly ill-structured | Medium to high | Very high | Very high | Very high to High | Very high |

**Table 1** continued

| Models | Format | PBL processes | | | | | Problem characteristic | Impact on learning outcomes (theoretically) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Problem solving reasoning led by | Content knowledge acquisition | Timing of knowledge acquisition and application | Problem solving process is a | Content contextual-ization | Structuredness | Efficiency of content knowledge acquisition/coverage | Knowledge application and transfer | Problem solving and reasoning skills | Self-directed learning skill | Ability to cope with uncertainty |
| Anchored instruction | Students possess basic content knowledge before engaging in the problem solving activities, which comprise the major portion of the course | Partial instructor and learner | Largely received from the instructor | Acquisition occurs first, then application follows. Additional content knowledge may be provided when needed during the problem solving process | Inquiry process with a support of learned basic content knowledge | Very high to high | Highly to medium ill-structured | High | Very high | Very high to High | High to medium | High to medium |
| Project-based learning | Learning initiated by lecture or students possess basic content knowledge before engaging in the project; project activities comprise the major portion of the course | Partial instructor and learner | Largely received from the instructor | Acquisition occurs first, then application follows. Additional situational knowledge may be acquired during the problem solving process | Inquiry process with a support of learned basic content knowledge | Very high to High | Highly to medium ill-structured | High | Very high | Very high | Medium | Very high to medium |

**Table 1** continued

| Models | Format | PBL processes | | | | | Problem characteristic | Impact on learning outcomes (theoretically) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Problem solving reasoning led by | Content knowledge acquisition | Timing of knowledge acquisition and application | Problem solving process is a | Content contextual-ization | Structuredness | Efficiency of content knowledge acquisition/ coverage | Knowledge application and transfer | Problem solving and reasoning skills | Self-directed learning skill | Ability to cope with uncertainty |
| Case-based learning | Learning initiated by lecture, companied with case analysis/ study (using solved problem) | Instructor | Completely received from the Instructor | Acquisition occurs first, then application follows | Realization of the manifestation of content knowledge in the problem | Medium | Medium to well-structured | Very high | High to medium | Medium | Low | Medium to very low |
| Lecture-based with problem solving activities | Learning initiated by and comprised with lectures, accompanied with a few problems for practice at the end of the course | Instructor | Completely received from the instructor | Acquisition occurs first, then application follows | Process of matching content knowledge to problem solving | Low to very low | Highly well-structured | Very high | Low to very low | Low to very low | Very low | Very low |

two PBL models that are geared toward traditional instructional methods could be more efficient than pure or hybrid PBL in guiding students to acquire intended content knowledge because learners' cognitive loads are reduced, as Kirschner et al. (2006) claimed. As a result, they could have produced learning outcomes in the students' content knowledge acquisition similar to traditional instruction as shown in the PBL literature. Following this line of reasoning, if a case-based learning course or even a lecture-based instruction accompanied with some problem solving activities is being claimed as a PBL course and compared to a traditional course, then the differences might not be notable because they are similar in terms of the cognitive requirements imposed upon the students.

*Curriculum and PBL problem design*

The design of PBL problems and curriculum is another potential area of concern. The systematic PBL implementations, such as PBL curricula in medical schools, McMaster University, Maastricht University, Delaware University, Samford University, or Illinois Mathematics and Science Academy (IMSA), might present fewer challenges for the faculty or those involved in the problem design process than the individual PBL educators who attempt to implement or incorporate PBL into their courses. The literature reports that designing effective PBL problems and curriculum is a challenge for individual educators (Angeli 2002; Goodnough and Hung 2008) because it is a time-consuming and research-intensive process.

How effective PBL problems have been in guiding students to study intended content knowledge is another question in the debate about its effectiveness. According to a number of studies that investigated how well instructor intended learning objectives corresponded to student interpretations of those objectives based on the problem statement given, the correspondence rate averaged only approximately 62% (from four studies: Coulson and Osborne 1984; Dolmans et al. 1993; O'Neill 2000; van Gessel et al. 2003). Though Dolmans et al. (1993) acknowledged that 47% of the unexpected learning objectives generated by the students could be rated relevant to the topic under study, more than 50% of them were irrelevant to the topic and could have caused distraction to the students' learning. Moreover, these reports were done in medical education contexts, in which the design of problems might be deemed as relatively more systematic in most cases—because of the advantages of departmental resources, support, or division of labor—than the problems used in individual instructors' PBL implementations. Thus, if the PBL problems designed by the faculty of a department or a designated instructional team were approximately 62% effective, the concern about the effectiveness of problems designed by individual instructors, which seems to be common in higher education and K-12 contexts (Maxwell et al. 2001), may be warranted.

This issue may well be one of the reasons for PBL students' slightly less desirable performance on content knowledge acquisition than traditional students as reported in PBL literature. Since PBL students' domain knowledge acquisition is derived from the problem solving process, if students cannot accurately identify intended learning objectives from the problem, a portion of their study could be devoted to indirectly related domain knowledge or general knowledge. When this occurs, the students' performance in the intended knowledge acquisition could be degraded. One may argue that this is the facilitator's responsibility to guide students to acquire intended content knowledge during tutorials, instead of investing substantial amounts of time in designing the problems. However, it was observed in a study of a PBL wildlife management course that, before the first tutorial meeting, the students in one group had spent more than 10 h researching federal funding agencies, which was relatively irrelevant to that particular problem (Hung et al. under review). Ineffective PBL problems and curriculum could undermine the effectiveness of PBL in students' activation of prior knowledge and their group processing (Gijselaers and Schmidt 1990; Perrenet et al. 2000), cause difficulty in generating learning issues that the problems are designed to cover (Dolmans et al. 1993), and affect students' self-directed learning (Gijselaers and Schmidt 1990). These deficiencies would inevitably reflect on the students' learning outcomes and might have distorted the effects of PBL reported in the literature.

## Issues related to human factors

### *Students' behaviors*

While the assumption that problem-driven instruction would trigger students' curiosity and desire to solve the problem, and therefore motivate and sustain students' self-directed learning behaviors during PBL processes may be true in some implementation cases, a number of reports revealed rather disappointing findings. For example, two comprehensive introspective evaluation reports from Maastricht University provided interesting insights. In the first report, Dolmans et al. (2001) observed some PBL student behaviors that they called "ritual behaviors," which refer to students maintaining superficial and minimum work to appear active in the learning process (e.g. making insufficient connections between new information and their prior knowledge). The second report by Moust et al. (2005) was a campus-level evaluation of the PBL implementations across programs and curricula at the Maastricht University. The deficiencies they identified in students' study behaviors in their PBL programs included insufficient self-study time, minimal preparation prior to tutorial group sessions, inadequate time devoted to searching literature and information, skipping brainstorming and elaboration during group discussions, and superficial synthesis of the investigation of the problem in the final reports.

Similarly, Taylor and Miflin (2008) indicated in their review of PBL implementations that it was a challenge to maintain students' interest in pursuing and engaging in the necessary cognitive processes such as generating learning issues. Rather, the students preferred to be given learning objectives. This lack of motivation and effort to engage in the learning process was also the serious issue identified in an external evaluation of the master's occupational therapy program at an Australian university (Vardi and Ciccarelli 2008). Moreover, Moust et al. (2005) observed that students would seek to obtain the tutor guide in advance, which contained pedagogical and content information for the facilitators to conduct tutorials. With the tutor guide available, the students would only study what was indicated in the tutor guide, instead of engaging in an inquiry investigation of the problem.

The theoretical assumption that problem-driven instruction motivates students' active learning failed the test in these PBL implementations. These ritual behaviors (Dolmans et al. 2001) not only undermined the students' learning of content knowledge in depth but also defeated the instructional objective of developing problem solving and self-directed learning skills, as Barrows defined (Barrows 1986).

### *Facilitators' behaviors*

Self-directed learning in PBL does not reduce the role and responsibilities of facilitators in the learning process. Instead, the facilitators play a pivotal role in the success of PBL implementation. PBL facilitators have to model problem solving and reasoning processes and guide students' learning processes, which demands a great amount of time and preparation. However, while the accusation by Kirschner et al. (2006) that PBL provides students with minimal to no guidance is a misconception, there were some instances that did validate this impression.

In his analysis of why PBL failed to deliver what it promises, Glew (2003) attributed one of the causes to facilitators' low attendance at the tutorial sessions. He pointed out that, in some instances, faculty facilitators attended only 20% of the tutorials. Also, some faculty who were required by the department to adopt a PBL curriculum might not have followed the tutoring guidelines from the curriculum designers. When this occurred, the effect of PBL would be confounded. This may shed some light on the rather surprising finding mentioned earlier from Koh et al. (2008), that PBL did not benefit the students' problem solving skills in the long term. If the facilitators failed to provide modeling and guidance for problem solving reasoning during the students' learning process, it might be safe to infer that the students might continue to employ intuitive reasoning processes or naïve causal reasoning (Perkins and Grotzer 2000), rather than develop scientific reasoning processes or a discipline-specific reasoning process.

The issue of insufficient guidance from the facilitator may be less of a problem in the case of individual PBL course implementations (non-departmental implementation) because the instructors presumably were highly motivated to take on the facilitator role and responsibilities. However, self-motivated PBL instructors may face the challenges of a lack of training on conducting a PBL course, limited (or no) support from the administration, and transitioning to assume the role of facilitators (Spronken-Smith and Harland 2009).

Conversely, there were some instances that were on the opposite end of the continuum in the amount of facilitation given by facilitators. Moust et al. (2005) reported that the fear of insufficient content coverage was still prevalent among the facilitators. As a result, facilitators tended to give more information than intended by the problems and curricula's design, or unconsciously reverted back to using lectures. Moust et al. (2005) even found that some facilitators gave the list of specific learning resources to the students, instead of a long list of potential resources that would require students to research and evaluate the relevance of the resources to the problem. They discovered that facilitators changed from providing general to specific references because of their lack of confidence in students' abilities to conduct such a task and cover intended content in a self-directed manner. The uncertainty about sufficiency of content coverage has been documented in the past (see, for example, Dods 1997; Schultz-Ross and Kline 1999; Lieux 2001; Angeli 2002; Hung 2006, 2009). It is noteworthy that this skepticism and concern is still a common belief, even among the educators who practice PBL after decades of implementation.

Either insufficient or excessive guidance from instructors presents potential damage to students' learning outcomes. Insufficient guidance could result in students deviating from the intended domain knowledge coverage or continuing to employ intuitive causal reasoning in the problem solving process instead of developing effective or discipline-specific problem solving skills. On the other hand, excessive guidance could undermine not only students' development of self-directed learning skills, but also their establishment of such a mindset.

*Resources and workload*

This area may seem to cause fewer difficulties than other troubled areas in PBL implementation. However, it could largely account for students' behaviors and facilitators' behaviors described above. The resource-intensive characteristic of PBL has long been a target of criticism (Farnsworth 1994; Colliver 2000). According to Barrows and Tamblyn (1980), the ideal group size is 6–8 students per group. To achieve this ideal size for the group to function effectively and efficiently, the school will inevitably need a much greater number of facilitators than they had before changing to PBL curricula. However, in reality, these types of resource increases, such as hiring more faculty members, have usually been a lower priority in an administration's resource allocation chart. Therefore, as Moust et al. (2005) observed, most schools solved these problems by increasing the group size. In Vardi and Ciccarelli's (2008) report, the number of students in each tutorial group ranged from 10 to 30 due to the limited number of facilitators and time constraints. Similarly, Moust et al. (2005) reported an inadequate student-facilitator ratio, with 12–19 students per group in a number of schools at Maastricht University. When a group reaches a size of 10 or even 30 students, the intended group processing functions such as collaborative learning are degraded.

Another issue is workload. Both students and facilitators have complained about the workload and demand on time (Vardi and Ciccarelli 2008; Hung et al. under review). To investigate a problem in depth requires a substantial amount of time to complete all the required tasks. Vardi and Ciccarelli (2008) found that the students spent 10–50 h per week just searching and filtering through information for their study. Unfortunately, they did not report sufficient details on some of the issues. For example, was there a correlation between the students' self-directed research abilities and the time spent on searching for information? How familiar were the students with PBL processes such as self-directed learning skills? A number of researchers have reported new PBL students' experiences of discomfort or anxiety due to unfamiliarity with the PBL process, especially with taking a more active, self-directed role in their own learning processes (Dabbagh et al. 2000; Fiddler and Knoll 1995; Lieux 2001; Schultz-Ross and Kline 1999). Schmidt et al. (1992) found that the students' transition from traditional lecture-based settings to PBL environments is a long and slow process. The uncertainty about their role in the learning process, what is expected of them, and which aspect of the problem they should focus on could cause anxiety (Lieux 2001) or result in ineffective research and learning of the topic (e.g. spending too much time on researching minor issues of the problem, Hung et al. under review). Nevertheless, these researchers' observations may imply that such a variable plays a role in students' PBL processes and, therefore, the facilitation of developing these skills could be critical.

On the other hand, to provide quality facilitation, facilitators would have to allocate more time to preparation as well as guiding students and giving feedback than they do in traditional teaching methods (Simons et al. 2004). As Koh et al. (2008) reported, PBL facilitators' student contact hours were 3–4 times greater than for instructors in traditional methods. Furthermore, Glew (2003) indicated that large amounts of nonteaching related demands and responsibilities imposed on the faculty inevitably undermined their ability to provide adequate facilitation to the students. Guiding students' learning entails much more time than simply giving students the answers. The administration's support for the faculty in this regard tended to be inadequately addressed in many PBL implementations. These resources and workload issues could have contributed to the negative effects on PBL students' and facilitators' behaviors discussed in the previous section and, consequently, could have affected students' learning outcomes.

*Small group learning*

As discussed earlier, small group learning in PBL provides not only an environment where students' learning outcomes and experiences can be enriched with the different perspectives brought in by the individual group members, but also ample opportunities for the students to develop the social skills they will need in their future personal and professional lives. However, small group learning is an aspect very sensitive to the "human factor" in determining the success of PBL implementation, as shown by the amount of discussion of dysfunctional groups in PBL literature.

Dysfunctional group interaction could be categorized into three types. The first deals with personality issues. When one or more group members who have dominating personalities take over the group's decision process, tension within the group is likely to occur (Hitchcock and Anderson 1997). This negative tension is one of the factors that can reduce the effectiveness of group processing. Conversely, group members with passive or subservient personalities could contribute little to the group problem solving and group learning process, which could hinder the attainment of positive learning outcomes (Steinert 2004; Wells et al. 2009).

The second type is uneven contribution or participation by group members. Some group members tend to contribute significantly less than their peers in a variety of ways, such as by missing meetings, being unprepared prior to the meeting, not completing assigned tasks on time (or at all), and not contributing in group discussions and decision making processes. Kindler et al. (2009, p. 868) characterized these negative behaviors as "tardy or absent," while other PBL practitioners referred to these students as "free riders" or "slackers" (Schwartz et al. 2001). These behaviors generated a sense of resentment from other group members and could even discourage students from participating in PBL courses.

The third type of group dysfunction results from a lack of social skills. From their interviews with the teachers who participated in a PBL implementation with 6th to 12th grade students, Achilles and Hoover (1996) reported some interesting findings. These teachers were surprised by the lack of proper social communication skills and etiquette the students exhibited during the PBL processes. These problems included being "distrustful of each other, wouldn't 'share' or willingly cooperate, and often displayed a 'me or them' attitude of survival" (p. 16). One may argue that maturity was responsible for these behaviors; however, these problems were not exclusive to K-12 settings. Bringing unsolved personal issues or conflict into the group, poor communication skills, or lack of support for other group members have also been reported in medical education contexts (Azer 2001), as well as in educational leadership graduate courses (Rose 2001).

The group dynamics issue is an extremely difficult management problem, as Hitchcock and Anderson (1997) suggested. It requires sophisticated tutoring and group management skills, which are often not readily possessed by the first-time instructor. Moreover, the benefits of small group learning assumed in PBL theoretical conception could be negated by these group processing issues. Therefore, group processing is an unpredictable variable in the success of PBL implementations because of its sensitivity to human nature.

In summary, the factors in PBL implementation that might have affected students learning outcomes could stem from PBL model variations, instructional design, and human factors. The studies referred to as PBL research or implementation in fact employed various PBL models that differed significantly in the degrees of self-directedness and problem structuredness, which could have resulted in very different instructional impacts on students' learning. Also, inconsistency in the quality of the PBL problems and curriculum design could have affected the student learning outcomes and in turn contributed to the inconsistent PBL research results. Furthermore, human factors were a variable that was unpredictable and very difficult to control in the processes of PBL research and implementation. Theoretically conceived PBL is based on an assumption of ideal conditions, such as intrinsically motivated students with a desire to solve problems and proper collaborative and social skills, ideal group size, enthusiastic tutors with sophisticated facilitation skills, and a supportive administration. When any one of these conditions does not meet the ideal, setbacks in the process will likely result in outcomes that differ from the theoretical promises. The implementation issues examined in this section confirmed this speculation.

## Can these problems be fixed?

When theory meets reality, issues and problems emerge as the reality (environment and the people) infuses numerous variables that could not have been accounted for during the conception of PBL. Thus, a discrepancy between theoretical promises and actual outcomes seems inevitable when a theoretically sound instructional method is implemented in real settings. However, this does not falsify the theoretical soundness of the instructional method. Instead, the realization of this discrepancy provides us with opportunities to refine the instructional method in order to achieve its original goal of enhancing students' learning. The examination in the previous section showed that the inconsistent or conflicting PBL research results might have stemmed from two main sources: research methods (the imprecision in referencing the PBL model) and implementation. Thus, to address the questions this paper intended to examine (debate about PBL) as well as to start a conversation for conceptualizing solutions to alleviate the implementation issues identified in this paper; research methods, instructional interventions, and administrative/organizational adjustments could be potential target areas. Yet, the complexity and ramifications involved in the discussion of administrative/organizational adjustment, which could range from the instructor's mindset and professional development to the departmental or campus administration's financial and structural support, is beyond the scope of this paper. Therefore, the following discussion will focus on remedial approaches from the perspectives of research methods and instructional interventions.

### Research methods

#### *Clarification of PBL model employed*

As discussed earlier, the existing PBL implementations consisted of a great number of variations. These variations of PBL could produce different degrees and types of instructional impact on students' learning outcomes. Therefore, the inability of previous research to accurately distinguish these differences might have been partially responsible for the inconsistent or conflicting results seen in PBL research. The purpose of this paper is not to advocate a certain PBL model as being superior to others, nor to unify all the variations into one best model that all PBL practices should follow. Each PBL model has its merits, strengths, and weaknesses. Perhaps, the research question should not be, "Is PBL effective?" or "Is PBL more effective than traditional instructional methods?" Rather, the question we should seek to answer may be, "Does each PBL model produce its desired effects in relation to its respective learner characteristics and instructional needs?"

To achieve this goal, PBL researchers and educators should carefully identify and report the following when sharing their research results: (1) the instructional needs that the PBL implementation is trying to fulfill, (2) learners' characteristics, (3) the PBL model used in their practice or studies, (4) the rationale for the PBL model selection, (5) the learning outcomes being measured, and (6) the type of assessment used. In terms of research, providing an operational description of these six aspects of a study is critical to providing a sound and useful research report (McMillan and Schumacher 2001), and in turn, to make PBL research sensible and meaningful. The report on the details of the model utilized is especially important. Without this information, comparative PBL research will not be possible and the debate about the effectiveness of PBL may never end. The categorization of the six PBL models discussed earlier in this paper, Barrows' taxonomy (1986), Hmelo-Silver (2004), or Harden and Davis' (1998) PBL model classifications could be used to identify and report the PBL model being utilized in the study so that this information could be more precisely conveyed to the researchers. Furthermore, the results from the PBL research that followed this format could provide educators and practitioners an efficient instructional guide for what PBL model is best suited for what type of instructional needs, as well as what type of learner groups.

*Assessment*

Assessment is a crucial component in improving PBL research. Unlike the assessment formats used in early PBL research, which were mainly standardized multiple choice questions testing for basic factual knowledge acquisition, performance-based, formative, multiple-source oriented formats have gradually become the mainstream assessment formats used in PBL. These assessments include, for example, the triple jump assessment (Smith 1993), objective structured clinical examination (OSCE) (van der Vleuten and Swanson 1990), clinical reasoning exercise (CRE) (Wood et al. 2000), practical portfolios (PPs) (Oberski et al. 2004), medical independent learning exercise (MILE) (Feletti et al. 1984), Group Assessment Task (Murphy and McPherson 1989), The 4 Step Assessment Task (4SAT) (Zimitat and Miflin 2003), and reflective journals (Ertmer et al. 2009). The focus of the PBL assessment formats has shifted to not only assess students' performance from multiple and diverse sources but also their learning processes.

These shifts in assessment formats in the PBL field have indicated the need for using appropriate assessment tools to measure intended learning outcomes. However, this also implies that each tool has its own specific features and functions for assessing specific areas of learning outcomes. Unfortunately, in their review of assessment instruments used in PBL research, Belland et al. (2009) found that the majority of PBL studies reviewed did not report on the validity (appropriateness) or reliability of their assessment instruments. Invalid assessment instruments could produce meaningless or even harmful data if these shortcomings were overlooked by anyone who used the data to conduct PBL research. Thus, PBL researchers must pay special attention to provide sufficient information on the validity and reliability of their instruments to avoid frustrating the PBL community and obscuring future PBL research directions.

Instructional interventions

Among other issues that could be remedied through instructional interventions, students' mindset and study habits may be the most fundamental. It has been documented that there is a transitional adjustment for many PBL students, for example, feeling overwhelmed or unsure about the expectations of them (Dabbagh et al. 2000; Hoffman and Ritchie 1997). The transition is especially difficult for students who are accustomed to traditional teaching and learning modes. These students have to not only adjust their study habits and behaviors from passively being told what to study to actively taking responsibility for deciding what needs to be studied, but they also have to psychologically take on the challenge of committing to this mindset change. Thus, this transition is not only behavioral but also psychological. Traditional teaching and learning modes have been and still are the dominant instructional methods in K-12 and college settings. Therefore, as some researchers have pointed out, it is not realistic to expect students, most of whom have studied under traditional curricula for approximately 15 years, to shift their study habits and mindset in a short period of time (Albanese 2000; Hung 2006). This shift in study habits from traditional to constructivist active learning requires an external behavioral change and an internal psychological mindset change, and this fundamental internal shift could be a long and difficult process. For some students who did not voluntarily enter a PBL curriculum, this supposed shift of mindset might never happen.

To help PBL students change their study behaviors, Moust et al. (2005) and Vardi and Ciccarelli (2008) have proposed a number of suggestions, such as developing computer-supported PBL environments or providing online resources, posing key conceptual questions prior to discussions, recording students' preparation, explicitly teaching discussion skills, using criterion-referenced grading, and adopting performance-based assessment; and, they have produced positive results (Vardi and Ciccarelli 2008). Changing students' external behaviors is necessary to help them achieve desired learning goals in the short term. However, this change may not be persistent if their internal mindset toward the learning shift (i.e., paradigm shift) does not occur. In the following, I will discuss some areas that may help PBL educators address these issues.

*Explicitly teaching PBL philosophy and process*

Humans are creatures of habit. Habits are especially difficult to change if there are no explicit or immediate benefits from the change. Also, students' old study habits could be resistant to change even when the instructional format has changed. One way to help PBL students make an efficient transition from a traditional learning mindset to a PBL mindset is to explicitly teach them the philosophy of PBL. As Smith and Ragan (2005) suggested, knowing why and knowing how are the affective and cognitive components that help individuals effectively change their habits or develop more appropriate attitudes. Knowing why (that is, the philosophy of PBL and rationale for the employment of PBL as the instructional method) may help the individual develop a positive attitude toward the instructional method. This positive attitude would likely promote more active engagement in the learning process and, in turn, result in effective learning outcomes as well as a change of mindset. Also, as Schmidt et al. (2007) contended, knowing "how" (that is, the process of PBL) would help students reduce unnecessary extraneous cognitive load (Sweller 1999; Van Merrienböer et al. 2006) and the anxiety from being unfamiliar with the instructional format; then as a result, they might actively take on their role in the PBL process and their own learning process. Thus, explicit instruction to orient the student to PBL could help students start their PBL experiences with a positive attitude and the study habits that are aligned with the PBL process.

*More systemic implementations of PBL in K-12 settings*

Explicitly teaching the PBL philosophy and process can be seen as a short-term goal for cultivating a healthy mindset for studying under the PBL format. In fact, what is more important, and should be a long-term goal, is to cultivate students' proactive, self-directed responsibility for their own learning from an early age. As appears in PBL literature, the systemic implementations of PBL predominately occurred in professional education and higher education. Though there are a few systematically designed K-12 PBL curricula (e.g. Buck Institute for Education, Illinois Mathematics and Science Academy (IMSA), Pedersen and Liu 2003), the implementation of PBL in K-12 settings in general is rather scattered and unsystematic (Ertmer and Simons 2006; Hmelo-Silver 2004). The instructional philosophy of PBL is a paradigm shift from traditional teaching and learning philosophy. It requires a fundamental restructuring of intellectual thought and growth to make the paradigm shift occur. It would be illogical and unreasonable to require students who enter a PBL curriculum to make psychological and behavioral adjustments and transition to close the philosophical gap in a short period of time. A reasonable solution to this problem could be promoting employment of PBL (with appropriate models) in early stages of students' academic learning careers, which is in K-12 settings. If students were exposed to PBL at an early age, it would naturally become part of their academic experience by the time they began their higher education.

*Providing appropriate scaffolding*

Effective problem solving skills or scientific inquiry skills are not instinctive for many students, both younger learners and adult learners. Researchers have discussed three main areas of deficiencies in learners' problem solving and scientific inquiry skills: initiating the problem solving process, using scientific causal reasoning, and evaluating the quality of the solution. First, some researchers have indicated that initiating the problem solving or inquiry process seemed to be difficult for the learners (e.g., Simons and Ertmer 2005) because they do not know how to ask the right questions (Kolodner et al. 2003). Second, most students tend to use a naïve, rather than scientific, causal reasoning approach during a problem solving or inquiry process (Perkins and Grotzer 2000), which can result in students' misconceptions. Third, students tend to be unable to see the importance of evaluating their solution to the problem (Krajcik et al. 1998). This may be due to their habits from the traditional learning environments where taking a final exam means the end of the learning of that particular subject.

These three issues may not be easily resolved by simply introducing the students to PBL early in their academic careers. Appropriate scaffolding is necessary for cultivating learners' abilities and habits of mind in assuming the role and tasks required in PBL environments. To provide appropriate scaffolding for PBL students, Simons and Ertmer (2005) suggested that sparking students' interest and reducing the tasks to a level deemed achievable by the students could alleviate their difficulty in initiating the inquiry process; engaging students in the scientific inquiry process could help students see their misconceptions; and providing prompts and modeling could promote students' reflective thinking about their solutions. While appropriate scaffolding is important during PBL processes, as Pea (2004) cautioned, fading is also critical and necessary in order to help the students to become independent, self-directed learners and problem solvers, as well as transfer knowledge and skills learned to novel contexts.

*Motivating students to be responsible active learners*

Another critical aspect is helping students develop the mindset of taking responsibility for their own learning. The theoretical conception of self-directed learning in PBL is described as "the preparedness of a student to engage in learning activities defined by himself rather than by a teacher" (Schmidt 2000, p. 243). Some researchers have observed that, even though students were actively engaged in researching solutions to the problems given, they were trying to detect what learning objectives and solutions the instructor had in mind or were specified in the tutor guide and then directed their learning toward those objectives (Schmidt 2000; Moust et al. 2005). This phenomenon is understandable because students' grades are involved. It also could be a residual effect from students' old mindset of traditional criteria-referenced grading systems, in which the principle of getting good grades means giving a performance that matches the instructor's specifications for success.

However, in PBL environments, the instructional goal is for the students to learn how to solve problems independently by conducting a scientifically sound research and reasoning process. That is, students must identify what the *problem* is and what needs to be researched and studied and then devise a solution. Thus, the criteria for evaluating PBL students should be whether the students can articulate the critical elements of the problem, their process for solving it, and the solution proposed and defend their proposed solution and the rationale, rather than whether they match predetermined answers. As Schmidt (2000) and Dolmans and Schmidt (1994) asserted, the way the students will be assessed largely dictates how they study. This assessment philosophy should not only be seriously taken into account when designing assessment in PBL, but also be explicitly conveyed to the students to reorient their mindset about grading, which would, in turn, reorient their mindset of the learning process as well as their responsibilities.

### *Importance of PBL curriculum and problem design*

One last aspect that could be remedied through instructional intervention is curriculum and problem design. Without carefully designed PBL problems and curriculum, the intentions for cultivating students' proper mindset of self-directed learning discussed above may be weakened. As mentioned earlier, in order for students to confidently direct their own learning, PBL assessment should focus on the students' abilities to direct their own learning and defend their own explanations and solutions. However, this assessment philosophy may become problematic if the problem can be reasonably interpreted and solved using knowledge that is irrelevant to the intended domain content area. Balancing between the "freedom to learn" (Schmidt 2000, p. 243) and curriculum intended objectives is a delicate line to draw. Designing appropriate and effective PBL problems and curriculum requires intensive analyses and design processes that should take a variety of critical components of a PBL problem into consideration to effectively and appropriately afford the intended learning goal (Hung 2006, 2009). For example, Hung (2006) suggested the 3C3R (content, context, connection, researching, reasoning, and reflecting) PBL problem design model for guiding instructional designers and educators to systematically consider the six critical core and processing components of PBL problems. Furthermore, Jonassen and Hung (2008) argued that all problems are not equal in affording all types of students' learning. Jonassen (2000) has constructed a comprehensive typology that consists of 11 types of problems, which differ in terms of the degree of structuredness, the problem solving process, the type of reasoning patterns required and the context. For example, some types of problems may more likely occur in specific professions than others, such as, diagnosis problems in medical fields or design problems in engineering. Thus, as Jonassen and Hung (2008) suggested, utilizing appropriate type of problems to provide the students with appropriate contexts as well as the unique characteristics of that type of problem is critical for ensuring the effectiveness of PBL instruction, and in turn, optimizing PBL students' learning outcomes.

## Conclusion

This paper examined the possible explanations for the inconsistent findings reported in PBL literature. These inconsistent or conflicting research results might have come from two sources: research methods and implementation. The imprecision in referencing the PBL model used in research creates a potential for a distortion of the PBL research results. Also, a variety of student and instructor behaviors that occurred during actual implementation were contradictory to PBLs theoretical assumption and could have confounded the PBL research.

The issues related to research methods could be alleviated with collective efforts from PBL researchers. However, the issues related to PBL implementation have more far-reaching implications than just an explanation for the unsettled debate. These issues are directly related to the performance of PBL students. Some issues are administrative, which are beyond the power of instructional interventions. However, some are instructionally correctable. The discussion and suggestions provided in this paper focused on the latter. To remedy students' undesirable behaviors that arise from the PBL process, students' fundamental mindset toward the instructional method and their own learning habits may be the key issue, and a number of suggestions were provided. The suggestions proposed in this paper are by no means ultimate solutions, but hopefully will serve as a starting point for the discussion of these important issues of utilizing PBL in education.

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