Interdisciplinary Journal of Problem-Based Learning

Volume 10 | Issue 2 Article 2

Published online: 8-1-2016

All PBL Starts Here: The Problem

Woei Hung
University of North Dakota, woei.hung@und.edu

THE INTERDISCIPLINARY JOURNAL OF
PROBLEM-BASED LEARNING

10TH ANNIVERSARY SECTION: PAST AND FUTURE

All PBL Starts Here: The Problem

Woei Hung (University of North Dakota)

Abstract

One essential piece of implementing of PBL is the problem. There have been calls from practitioners in the PBL field for a systematic process for designing effective PBL problems. Yet, the research efforts to explore, develop, and test PBL problem design methods or processes are still sparse. From an instructional designer and researcher's perspective, I deem problem design to be the first step to ensure not only the proper affordance of the learning goal but also the students' overall learning process in PBL implementation. PBL problem design is the area I have studied most consistently and passionately. In this paper, I share my continuing study of PBL problem design, from the original 3C3R model and the 9-step design process, to an examination of the cognitive components of PBL problems such as problem difficulty structure and levels, to my recent focus on the affective components of PBL problems.

Keywords: PBL problem design, PBL implementation, cognitive process, problem difficulty, affective effects of PBL problems

Introduction

Previously trained as an objectivist researcher, I underwent a paradigm shift when I was introduced to constructivism and problem-based learning (PBL). The shift was neither difficult nor shocking, but rather an elucidating experience. Since then, I have immersed myself in the realm of PBL and become a firm believer in it. Having said that, I have to also make it clear that I do not think PBL is an almighty instructional method that is perfect for all instructional and learning needs. Every instructional method has its place in education. The question is when to use each one.

As we all know, PBL was originally formulated to address the issue of students' inability to apply knowledge learned and solve problems in real-world situations (Barrows & Tamblyn, 1980; Albanese & Mitchell, 1993; Barrows, 1996). Conceivably, the main focus of instruction is to help students develop the ability to solve real-world problems. In PBL, this focus is operationalized by means of problems. PBL problems serve a number of functions. Problems trigger students' motivation to study necessary content knowledge. Problems afford the content knowledge to be studied. Problems contextualize the content knowledge. Problems provide a workspace for students to apply the content knowledge. When encountering a problem that makes students realize what knowledge they are lacking, it motivates them to study the content information. Working with a real-life and authentic problem from the field of a profession gives meaning to the abstract content knowledge involved in the problem. When students personally work through a problem using newly learned knowledge, they understand the knowledge at a much deeper level. Problems not only trigger learning, but also afford the entire learning process of PBL. Thus, as the title of this paper suggests, all PBL starts here: the problems.

As critical and fundamental as they are, problems and their design have received far less attention than have other research areas of PBL (such as effectiveness of PBL, tutors' roles and skills, or group processing). I came to realize this underdeveloped area of PBL 12 years ago one day when I was trying to design some PBL problems for a course. When I started the design process, I found myself with only a vague direction as to how to proceed. This experience took me by surprise because with my background and knowledge in PBL and instructional design I did not anticipate such difficulty in designing problems. The first action I took, of course, was to turn to the PBL literature and books. Yet, what I found were lists of guidelines describing problems and how they should look; for instance, authentic, real-life, complex, and ill-structured (e.g., Dolmans & Snellen-Balendong, 1997; Torp & Sage, 1998). These guidelines were very useful in terms of describing the characteristics of PBL problems. However, they still did not help me learn how to get started

http://dx.doi.org/10.7771/1541-5015.1604

and design a PBL problem. There was no systematic conceptual framework or design process available in the literature. This made me realize that if I, an instructional designer with a fairly substantial amount of knowledge about PBL, had difficulty designing PBL problems, there were probably other PBL practitioners (especially new PBL educators) who experienced such struggles. With this realization, I started researching the literature of PBL, cognitive science, problem-solving processes, and instructional design. The result of this work was the proposal of my first conceptual framework: the 3C3R PBL problem design model. The paper was first presented at a PBL special interest group (SIG) paper session at American Educational Research Association (AERA) in 2005. I remember that John Savery was the discussant and he said to me, "You need to publish this paper." Peg Ertmer and Alexius Macklin, the founding editors of IJPBL, were also in the audience and later invited me to submit the paper to the journal. For a recent PhD graduate and young faculty member, these words of encouragement were a huge deal to me. That paper then became the first article that I published in IJPBL: "The 3C3R Model." Since then, PBL problem design has been, among others, my primary research area. I will now share my continuing study of PBL problem design, from the original 3C3R model and the 9-step design process, to an examination of the cognitive components of PBL problems such as problem difficulty structure and levels, to my recent focus on the affective components of PBL problems.

The 3C3R Model

The 3C3R PBL problem design model (Hung, 2006) is a conceptual framework that describes the critical components in a PBL problem. It is to guide instructional designers and educators to design effective PBL problems for all disciplines and all levels of learners. This is achieved by aligning proper affordance of the problem with the learning objectives of the PBL module through adjusting different components of the problem. The framework helps guide instructional designers to systematically consider this set of problem components to better afford students in developing their domain knowledge base, problem-solving and reasoning skills, and profession-specific/cultural dispositions. The 3C3R model consists of two classes of components: core components and processing components. Core components include content, context, and connection that mainly deal with the design of the problem in support content/concept learning. They primarily address the issues of appropriateness and sufficiency of content knowledge, knowledge contextualization, and knowledge integration. On the other hand, the processing components, which are researching, reasoning, and reflecting, concern the learners' learning processes and problem-solving skills. These components function to guide students' learning toward the intended learning goal and objectives—adjusting the level of cognitive processing required to solve the problem to the cognitive abilities of the learners, and alleviating students' initial unfamiliarity and/or discomfort with PBL.

One may question the necessity of systematically designing PBL problems and adjusting the problems (or problem statements) to guide students' learning because the students can be directed by facilitators. There is no question about the importance of the tutor's role to student success in the PBL process. However, placing all bets on facilitators is risky for a number of reasons. First of all, the quality of facilitation varies from one facilitator (or institution) to another (e.g., Glew, 2003). Even with proper training, there is still no guarantee that all the facilitators will follow the facilitator guides and protocol. Second, if the problem is so vague or difficult that the students do not even know where to start and therefore have to be laboriously guided by the facilitator, there could be a risk that the students might develop a dependency on the facilitator for guiding them through the PBL process (Hung, Mehl, & Holen, 2013). This would defeat the goal of developing their independent problem-solving abilities. Third and perhaps most critically, we need to help students develop their scientific problem-solving abilities and dispositions. Albanese and Mitchell (1993) have reported students' tendencies to employ a backward reasoning PBL process, which is not a scientifically sound problem-solving approach. By using this approach, students first jump to the step of devising a solution to the problem, and then work their way back to collect data to confirm or reject the solution. On the other hand, the scientific problem-solving process (forward reasoning) requires the problem solver to first understand the problem (Bransford & Stein, 1984; Polya, 1957) and construct the problem space (Newell & Simon, 1972). Without a clear understanding of the problem and a depiction of the problem space, he or she may miss critical parts of the problem, misinterpret what the goal of solving the problem is, or miss the whole picture of the problem.

Besides the possibilities of lack of scientific problem-solving skills or lack of motivation to study diligently, students' tendencies to skip the step of understanding problems could stem from ill-designed problems. Hung and Holen (2011) and Hung, Mehl, and Holen (2013) have reported that the students found many problems in their PBL courses were too broad and vague for them to confidently identify the goal or focus of the problem as well as the learning objectives. When students have difficulty in identifying or misidentify what content knowledge and/or skills the problem intends for them to study, their frustration is not unreasonable. If this is a reoccurring experience for the students, skipping the step of understanding the problem is a likely consequence.

All PBL starts from encountering a problem. All learning in PBL starts from understanding the problem, which is represented in the problem statement. This first step is not only critical to students' problem-solving processes, but also their learning processes; for example, the elaboration process (e.g., 7-jump PBL process, Schmidt, 1983), which is built upon a thorough understanding of the problem.

A PBL problem is not just the problem statement, but the entire PBL module. However, the problem statement is the students' first encounter with the problem. It sets the stage, parameters, context, and boundaries for the problem. And more importantly, it sets the environment for the learning. Then what are the steps needed for PBL practitioners to systematically consider all core components and processing components of the problem? Based on the 3C3R model, I developed the 9-step PBL problem design process.

The 9-Step PBL Problem Design Process

The 9-step problem design process is a step-by-step process specifically for designing PBL problems using the 3C3R model (Hung, 2009). Contrary to some who equate constructivist instruction (including PBL) to a free form of inquiry where students are encouraged to explore whatever they wish, PBL and constructivist instruction in fact have specific learning goals and objectives to achieve. In order for students to be able to acquire and construct the intended knowledge on their own terms, the instruction and the learning environment require a much more rigorous design process and "careful orchestration" (Kolodner, 2002, p. 123) to achieve such a task. The 9-step design process was conceived to provide PBL practitioners with a tool to systematically conduct this design process.

The 9-step method builds intensive analysis and calibration of the problem into the design process. This is to ensure that the design of the PBL problem appropriately and holistically affords student learning in all aspects of content acquisition, problem-solving skills, and self-directed learning. The first three steps (Step 1: *Set goals and objectives*; Step 2: *Conduct content/task analysis*; Step 3: *Analyze context specification*) are a front-end analysis of the PBL module. Step 4 (*select/generate PBL problem*) and Step 5 (*conduct PBL problem affordance analysis*) are the analysis of the selected PBL problem. Step 6 (*conduct correspondence analysis*) and Step 7 (*conduct calibration processes*) are the analyses of affordance and adjustment of the PBL problem. Step 8 (*construct reflection component*) describes the design of the reflecting component. Finally, step 9 (*examine inter-supporting relationships of 3C3R components*) examines the integrity of the 3C3R components of the problem.

The purposes of these analyses and calibrations are not to prescribe students' learning processes or outcomes. Rather, they are to determine the appropriate amount of information to be included in the problem statement for guiding students to the intended learning objectives and content knowledge. This guiding information in the problem is not directions that tell students what to do or what the learning objectives are, but clues that could direct them (if they pay attention to these clues as they should in solving any real-life problems) to take the path where the intended content knowledge will be or avoid the paths that are too far off from the learning objectives. PBL problems are complex and ill-structured in nature. Therefore, quite often the scope of PBL problems are larger and far more complex than the intended learning goal and objectives for the PBL modules, which I call "overaffording" PBL problems (Hung, 2009). One real example that happened in my instructional design class is that one student selected "running a bakery" as a PBL problem for teaching her students four basic mathematical computations. At first, it seems to be a reasonable and fun problem that would afford her students to learn to use the four basic mathematical computations in engaging in the problem-solving process. After she conducted the problem affordance analysis, however, she found that the tasks involved in the problem of "running a bakery" included decisions on buying or renting equipment, setting store hours, hiring a number of helpers, pricing of the products, etc., and then calculating costs, profits, and balance. With this analysis, she realized the scope of the "running a bakery" problem was way larger than what the target learning goal was. Subsequently, she was able to reduce the scope of the problem (problem space) by adjusting the problem scenario to "determining prices to meet monthly sales goal."

Indeed, in some cases, it is necessary to set a boundary for the problem space (Newell & Simon, 1972), or reduce the chance for the students to take the path that is not part of the intended learning objectives. This should not be done by telling students what to do or what not to do. Instead, this should be integrated as part of the contextual information of the problem statement. For example, in a PBL wildlife management course (Hung, Mehl, & Holen, 2013), one of the groups spent two days researching federal funding opportunities and agencies, which was not part of the module or course learning objectives. Cases such as this, including information such as "this project is not qualified for federal funding as the wetland is not within a federal conservation area" may help avoid the issue. Also, the function of calibrations is to set an appropriate level of problem difficulty to afford the level of the students' cognitive maturity or learning stage. Problems are like puzzles. The amount and types of information included in the problem are positively (guiding) or negatively (misleading) correlated with the level of problem difficulty (Jonassen & Hung, 2008). Therefore, by adjusting the amount of information given or left out of the problem, we can calibrate the problem to properly guide students to the intended learning objectives, and to better afford the students' learning according to their cognitive abilities or stages of learning.

The effectiveness and usefulness of the 3C3R model and the 9-step design process has been tested by a number of studies (e.g., Goodnough & Hung, 2008, 2009; Tawfik, Trueman, & Lorz, 2013; Xue, et al., 2013). For example, Goodnough and Hung (2008, 2009) obtained positive results from helping elementary school science teachers design effective PBL problems using the model and the design process. Also, Tawfik, Trueman, and Lorz (2013) reported an implementation of the model and process in their case study of designing PBL problems for a human biology course. One specific example was that using the model and the design process helped them realize a missing piece of information whose absence could reduce the possibility for the students to identify ethinyl estriadol as a variable for the patient's symptoms in the problem. Furthermore, the 3C3R model and the 9-steps PBL problem design process has also been used in improving PBL problems and curriculum. For example, Xue and colleagues (2013) randomly assigned 139 medical students to the traditional PBL problem group and the 3C3R modified problem group, with 76 students and 63 students respectively. A survey was administered after the implementation, and the results showed students were consistently in favor of the 3C3R modified problems in facilitating the PBL learning process. Specifically, the number of 3C3R modified problem students (agreed or strongly agreed) who deemed that the problem helped their reflection process significantly outnumbered that of the traditional PBL problem students (40.8% versus 76.2%, $p < 0.05$), while, though not significantly, the 3C3R group appreciated the problem more than the traditional PBL problem group did in all other components. The tutors shared similar perceptions. Furthermore, Hung, Love, and Fu (2012) compared 24 wildlife management students' generated learning objectives and the instructor intended learning objectives from four problems. Among the four problems, problem 1 (Oakville Prairie Management Plan) was the only problem designed using the 3C3R model and the 9-step design process. However, this information was not disclosed to the students. We found that a statistically significant difference was found between problem 1 and problem 2 ($t = 3.056$, $df = 32$, $p < 0.005$) as well as between problem 1 and problem 4 ($t = 3.336$, $df = 34$, $p < 0.005$) in terms of the correspondence rates between student generated and the instructor intended learning objectives. Though the difference between problem 1 and problem 3 for the correspondence rates was not statistically significant—it was marginal ($t = 1.934$, $df = 34$, p = 0.06)—these results were encouraging.

The 3C3R model and the 9-step design process aim to provide a conceptual framework to guide instructional designers and PBL educators to design more effective PBL problems that precisely afford the curriculum standards and learning goals, appropriately meet learners' characteristics, and reflect implicit clinical constraints, rather than leaving these aspects entirely to the students' or tutors' interpretations. The results of the analyses (e.g., problem affordance analysis or correspondence analysis) conducted in the 9-step design process can also be incorporated into the tutor's guide to provide them with additional information, such as competing hypotheses, alternative reasoning paths, and competing solutions or interpretations, as well as the rationales. This information could give the tutors (especially non-expert tutors) a better mental model of the problem space for guiding the students through the problem-solving process. Also, the 3C3R model and the 9-step process can serve as a conceptual framework for evaluating the appropriateness and effectiveness of PBL problems.

Complexity and Structuredness of PBL Problems

To calibrate problems to appropriately afford students' cognitive abilities during the PBL process, problem difficulty level is a component that cannot be missed in the profile of PBL problems. As David Jonassen and I (2008) pointed out in our paper, "All problems are not equal"; the problem difficulty level is usually determined based on the designer's experience or intuition during the design process, or, based on students' actual performances solving the problems after the fact. According to Wood (1985), problem difficulty is defined as a probability of being successfully solved by a problem solver. From an instructional design perspective, it is more desirable if this probability can be analyzed as much as possible during the design process in order to reduce students' frustrations and detrimental effects on their learning experiences.

To address this aspect of PBL problems, Dave and I (2008) identified complexity and structuredness as two main external dimensions (as opposed to internal dimensions, such as a problem solver's own cognitive ability) that account for the difficulty level of a problem. We further dissected these two dimensions into more specific and descriptive parameters so that they would be useful for PBL practitioners to assess a PBL problem in terms of its difficulty level in the design process. Specifically, problem difficulty can be analyzed by the nature and level of the complexity and structuredness dimensions of a problem. The dimension of complexity describes problems in terms of the breadth, attainment level, intricacy, and interrelatedness of the problem space. Structuredness, on the other hand, describes problems in terms of the transparency, stability, and predictability of the problem space.

Parameters of Problem Complexity

The dimension of complexity comprises four parameters: breadth of knowledge required to solve the problem, attainment level of domain knowledge, intricacy of problem-solution procedures, and relational complexity. First of all, breadth of knowledge refers to the amount of domain knowledge needed in order to solve the problem. This parameter determines the scale of a problem because the difficulty of problems varies positively with the size of the problem space, according to Kotovsky, Hays, and Simon (1985). Generally, the greater the amount of general and domain knowledge required for solving a given problem, the greater the size of the problem space, and therefore, the more complex the problem. This knowledge includes the factual information, concepts, principles, and procedures needed for solving the problem (Sugrue, 1995). Second, attainment level of domain knowledge addresses the difficulty level of comprehending or applying the concept. Abstractness of the concepts (Bassok, 2003), difficulty in grasping (Kotovsky et al., 1985), and the level of advancement of the concepts required are the three factors that could affect the level of problem difficulty. Third, the parameter of intricacy of problem-solution procedures is the solution path length (Hays & Simon, 1974), which refers to the number of steps to be executed in a solution path and the extent of complexity of the tasks and procedures in these steps. It has also been referred to as computational complexity, which is measured by the time needed to solve a problem (Quesada, Kintsch, & Gomez, 2005). Lastly, the parameter of relational complexity is described by Halford, Wilson, and Phillips (1998) as the number of relations that need to be processed in parallel during a problem-solving process, much like cognitive load. The more complex the relations in a problem, the more processing load is required during problem-solving, and as a result, the more complex the problem is.

Parameters of Problem Structuredness

Wood (1983) defined the structuredness of a problem as the degree to which the ideas in the problem are known or knowable to the problem solver. The dimension of structuredness consists of five parameters: intransparency, heterogeneity of interpretations, interdisciplinarity, dynamicity, and legitimacy of competing alternatives. The first parameter of problem structuredness is intransparency. This parameter describes the unknown portion of the problem space. Most problem-solving researchers agree that unknowns in the problem space are one of the features that make problems ill-structured (Frensch & Funke, 1995; Spering, Wagener, & Funke, 2005). The higher the degree of intransparency (that is, the more we do not know about the problem), the more ill-structured the problem is. Secondly, the parameter heterogeneity of interpretations refers to the number of possible interpretations and perspectives for understanding or solving the problem. The more open the problem is to interpretations, the more ill-structured the problem is. This heterogeneity of interpretations of a problem could be the openness of the problem space or the solutions. When the problem is vaguely defined, it is considered highly ill-structured. Also, when the criteria of evaluating the viability of the solution are vague, the problem is highly ill-structured. The third parameter is interdisciplinarity. The degree of interdisciplinarity affects the level of problem structuredness in two ways. When a problem requires interdisciplinary knowledge or considerations to solve it, one critical element to successfully solve the problem is making sure that all facets (disciplines) have been taken into account. Also, because of the interdependency of the various disciplines, changing a subdecision in one area will subsequently affect others. As a result, the task of balancing all aspects of the problem makes solving this type of problem a challenge. Fourth, dynamicity is one of the defining properties of ill-structured problems agreed on by many problem-solving researchers (Frensch & Funke, 1995), which describes the instability of the variables and states in the problem throughout the problem-solving process. This is also referred to as continuity by Bassok (2003). Dynamic variables are often emergent in nature. There are emergent properties in some cases that only appear in response to the changes of other related variables or states of the problem or certain actions taken by the problem solver. Lastly, the parameter of legitimacy of competing alternatives refers to the extent to which the number of conceivable options for executing operators in various states and solution paths exists within the problem space. On the continuum of structuredness of problems (Jonassen, 1997), extremely well-structured problems possess one single, prescribed solution path, while extremely ill-structured problems possess an indefinite number of solution paths, which inevitably increases the difficulty level of solving the problem.

This conceptual framework equips PBL practitioners with a powerful tool for analyzing the difficulty level and profile of a given PBL problem. With this analysis, instructional designers of PBL problems will be in a better position to select problems with an appropriate difficulty level and profile, or calibrate the problem that has been selected to appropriately afford the students' cognitive abilities, and therefore, enhance their learning effectiveness and experiences.

Affective Components of PBL Problems

As mentioned earlier, in PBL, problems give meaning to abstract content knowledge by connecting it to real-life situations. With these connections, the students can develop their situational knowledge to index their content knowledge so that they know when, where, and how to use it. The 3C3R model was conceived mainly to address cognitive processing and learning environment (such as professional, situational, social, or cultural variables) in a PBL learning process. While continuing my research on PBL, a new component of PBL problems came to light in one of my studies (Hung & Holen, 2011), that is, the affective component. In investigating students' perceptions about their learning experiences and the effects of complexity and structuredness of PBL problems on their learning processes, we found that many students developed a strong sense of ownership of the problem. When we looked closer at their responses to our interviews, we found that they took the problem into their own hands and hearts, not because of the problem but because of the person in the problem and where the problem occurred. One particular response from a student who said "having a problem this close to home really hit me" was a light bulb moment for me. From that study, we identified four elements in the affective component of PBL that could have psychological or emotional effects on students' development of ownership, relatedness, and in turn, their engagement and motivation to solve the problem and study the learning materials. These four elements are as follows: unsolved real-life problem, time proximity, location proximity, and subject presence. In a subsequent study (Hung, Mehl, & Holen, 2013), we identified two more elements: personal interest and career interest.

As we know, self-directed learning is one of the main characteristics of PBL (Barrows, 1996; Norman & Schmidt, 1992). However, a real-life problem alone may not be an automatic motivator for the students to fully and mindfully engage in the learning process, as more and more studies are reporting students' disengagement or taking shortcuts (e.g., Dolmans, Wolfhagen, van der Vleuten, & Wijnen, 2001; Romito & Eckert, 2011; Moust, van Berkel, & Schmidt, 2005). According to Deci, Vallerand, Pelletier, and Ryan (1991), one component of motivation is basic psychological needs. For students to be intrinsically motivated to engage in self-directed and self-regulated learning, the desire to solve the problem and study the topic needs to be self-determined, rather than forced or coerced by external influence. Deci and Ryan's (1985) self-determination theory (SDT) argues that self-determination is the essence of intrinsic motivation and continuing motivation. They explained that in educational settings providing support for fulfilling their basic psychological needs for competence, relatedness, and autonomy is a key to promoting students' motivation in learning. They further elaborated that competence involves a desire of possessing necessary knowledge and skills that enable an individual to accomplish a goal. Relatedness refers to the social needs of humans to connect with others. Lastly, autonomy may be the core of the SDT that a motivated action or behavior is self-initiated and self-regulated, rather than controlled. Among these three psychological needs, relatedness may be the most "instructionally designable," as the other two have been fully addressed in the PBL process and method. Carefully designing the PBL problem that triggers the students' psychological needs of connecting with others could also promote the need for competence, and therefore strengthen their motivation to learn.

Unlike textbook problems, PBL problems are real-life stories. They are stories occurring in a person, a group of people, objects, a habitat, or animals in a particular place at a particular time. However, we found that real-life problems alone do not necessarily promote the students' sense of ownership or personal connection to the problem and therefore motivate them to solve the problem (Hung & Holen, 2011; Hung, Mehl, & Holen, 2013). Rather, real-life problems that promote the psychological needs of relatedness and SDT could increase the chance for the students to develop such connection to and ownership of the problem. We found that psychological/emotional elements such as location proximity, subject presence, and others mentioned above may play a pivotal role in triggering such connection between the problem and the problem solver (i.e., the students in PBL). It is not difficult to imagine what differences the following two problems could make: (1) a problem that requires engineering students to design a wearable robotic device for a manufacturer that will assist individuals whose lower body is paralyzed to walk; versus (2) a problem that tells a real story about a 7-year-old boy whose lower body is paralyzed from a car accident (showing pictures of him running in the grass before the accident, and having him come to the class sitting in a wheelchair to tell his story) and requests engineering students to design a wearable robotic device for him and patients like him so that he can walk and run again.

It is known in the field of PBL that authenticity is one of the essential characteristics of PBL problems. However, from our studies (Ak, Hung, & Holen, 2012; Hung & Holen, 2011; Hung, Mehl, & Holen, 2013; Hung, Ak, & Holen, 2013), we realized that there are more elements in the problems that may influence students' motivation and engagement during the PBL process. Identifying these affective elements of PBL problems helps us to have a better understanding of the nature and components of a PBL problem and how to select problems to not only afford the intended learning objectives and problem-solving skills development, but also promote the level of motivation and engagement of students in the learning process. The six elements (subject presence, location proximity, temporal proximity, personal interests, career interests, and unsolved problem) that we identified would be helpful in giving PBL practitioners some directions to consider when selecting and designing their PBL problems. Furthermore, we also noticed that these affective elements may not have the same level of effect on the students' motivation and engagement levels during the PBL process. In two subsequent studies, we found that the teacher education students rated subject presence and career interest over the other elements in promoting their motivation and engagement (Ak, Hung, & Holen, 2012). Also, students from different cultural backgrounds deemed the levels of these affective elements differently in promoting their motivation and engagement (Hung, Ak, & Holen, 2013). One finding from Ak, Hung, and Holen's (2012) study surprised us in that career interest was rated 1 point higher than personal interest on a 1–5 point Likert scale. Could this finding be a result of the students having been junior and senior college students whose primary concern was job preparation? If so, the findings that we obtained from these studies should not be taken as they are. Perhaps the interactions between these affective elements and other variables such as students' levels (e.g., freshman vs. senior year or professional students vs. middle school students) or disciplines (e.g., engineering vs. history) would shed better light in showing the roles of these affective elements in students' learning processes in PBL.

Conclusion

More research findings lead to more research questions, which seems to be an endless chase. Yet, curiosity about the unknown and a desire to solve problems have driven humans to where we are today. PBL bases its pedagogy on this very nature of humans. Five decades since it was first conceived and implemented, PBL not only survives rigorous testing and strong skepticism and criticism, but grows exponentially and prolifically (Hung, 2011; Hung & Loyens, 2012; Loyens, Kirschner, & Paas, 2011). Student learning outcomes have spoken for PBL (Albanese & Mitchell, 1993; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Kalaian, Mullan, & Kasim, 1999; Norman & Schmidt, 1992). The forte of PBL is helping students develop the ability to use domain knowledge in solving real-world problems and work collaboratively with others, which are the skills that society desires today and foreseeably in the future. Therefore, it is my belief that PBL is here to stay, for a very long time, if not forever.

PBL is a complex instructional method that requires thorough analysis and thoughtful planning in order to compose a choreography where its different parts (such as tutors' facilitating students' learning, students' group dynamics and processing, etc.) work complementarily and in sync for the system to take effect as it is designed. Most important of all, let's not forget Barrows's (1996) wisdom, which states "the curricular linchpin in PBL—the thing that holds it together and keeps it on track—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" (p. 8). All PBL starts from problems, processes through problems, and ends with learning from problems. I encourage PBL researchers to join the effort in researching PBL problem design.

References

Ak, S., Hung, W., & Holen, J. B. (2012, April). Problems and motivation in Problem-based Learning: A case study. Paper presented at *AERA Annual Meeting 2012*, Vancouver, BC, Canada.

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*, 52–81.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. In L. Wilkerson & W. H. Gijselaers (Eds.), Bring problem-based learning to higher education: Theory and practice. *New Direction for Teaching and Learning, 68*, 3–12.

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer.

Bassok, M. (2003). Analogical transfer in problem solving. In J. E. Davidson & R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 343–369). New York: Cambridge University Press.

Bransford, J. D., & Stein, B. S. (1984). *The IDEAL problem solver*. New York: W. H. Freeman.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *The Educational Psychologist*, *26*, 325–346.

Dolmans, D. H. J. M., & Snellen-Balendong, H. (1997). *Seven principles of effective case design for a problem-based curriculum. Medical Teacher, 19*(3), 185–189.

Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., van der Vleuten, C. P. M., & Wijnen, W. H. F. W. (2001). Solving problems with group work in problem-based learning: Hold on to the philosophy. *Medical Education, 35*, 884–889.

Frensch, P. A., & Funke, J. (1995). Definitions, traditions, and a general framework for understanding complex problem solving. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European perspective* (pp. 3–25). Hillsdale, NJ: Erlbaum.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75,* 27–61. http://dx.doi.org/10.3102/00346543075001027

Glew, R. H. (2003). The problem with problem-based medical education: Promises not kept.
Biochemistry and Molecular Biology Education, 31(1), 52–56.

Goodnough, K., & Hung, W. (2008). Designing effective problems: Evaluation of 3C3R 9-step design process. *Interdisciplinary Journal of Problem-based Learning, 2*(2), 61–90.

Goodnough, K., & Hung, W. (2009). Enhancing teacher pedagogical content knowledge in the context of elementary science. *Teaching Education, 20*(3), 229–242.

Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral & Brain Science, 21*, 803–864.

Hays, J. R., & Simon, H. A. (1974). Understanding written problem instructions. In L. W. Gregg (Ed.), *Knowledge and cognition* (pp. 167–200). Hillsdale, NJ: Erlbaum.

Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. *Interdisciplinary Journal of Problem-based Learning, 1*(1), 55–77.

Hung, W. (2009). The 9-step process for designing PBL problems: Application of the 3C3R model. *Educational Research Review, 4*(2), 118–141.

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research & Development*, *59*, 118–141.

Hung, W., Ak, S., & Holen, J. (2013, April). A cross-cultural study of problems elements and motivation in PBL: A comparison of US and Turkish pre-service teachers. Paper presented at *AERA Annual Meeting 2013*, San Francisco, CA.

Hung, W., & Holen, J. B. (2011). Problem-based learning: Preparing pre-service teachers for real world classroom challenges. *ERS Spectrum, 29*(3), 29–48.

Hung, W., Love, S., & Fu, H. (2012, April). Enhancing learning effectiveness in problem-based learning: Can problem design help? Paper presented at *AERA Annual Meeting 2012*, Vancouver, BC, Canada.

Hung, W., & Loyens, S. M. M. (2012). Global development of problem-based learning: Adoption, adaptation, and advancement. *Interdisciplinary Journal of Problem-based Learning, 6*(1), 4–9.

Hung, W., Mehl, K., & Holen, J. B. (2013). The relationships between problem design and learning process in problem-based learning environments: Two cases. *The Asia-Pacific Education Researcher, 22*(4), 635–645. http://dx.doi.org/10.1007/s40299-013-0066-0

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *ETR&D, 45*(1), 65–94.

Jonassen, D. H., & Hung, W. (2008). All problems are not equal: Implications for PBL. *Interdisciplinary Journal of Problem-Based Learning, 2*(2), 6–28.

Kalaian, H. A., Mullan, P. B., & Kasim, R. M. (1999). What can studies of problem-based learning tell us? Synthesizing and modeling PBL effects on National Board of Medical Examination performance: Hierarchical linear modeling meta-analytic approach. *Advances in Health Sciences Education, 4*, 209–221.

Kolodner, J. L. (2002). Analogical and case-based reasoning: Their implications for education. *The Journal of the Learning Science, 11*(1), 123–126.

Kotovsky, K., Hays, J. R., & Simon, H. A. (1985). Why are some problems hard: Evidence from Tower of Hanoi. *Cognitive Psychology, 17*, 248–294.

Loyens, S. M. M., Kirschner, P., & Paas, F. (2011). Problem-based learning. In S. Graham (Editor-in-Chief), A. Bus, S. Major, & L. Swanson (Associate Editors), *APA educational psychology handbook: Vol. 3. Application to learning and teaching*. Washington, DC: American Psychological Association.

Moust, J. H. C., van Berkel, H. J. M., & Schmidt, H. G. (2005). Signs of erosion: Reflections on three decades of problem-based learning at Maastricht University. *Higher Education, 50*, 665–683.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine*, *67*, 557–565.

Polya, G. (1957). *How to solve it: A new aspect of mathematical method*. Princeton, NJ: Princeton University Press.

Quesada, J., Kintsch, W., & Gomez, E. (2005). Complex problem-solving: A field in search of definition? *Theoretical Issues in Ergonomics Science, 6*(1), 5–33.

Romito, L. M., & Eckert, G. J. (2011). Relationship of biomedical science content acquisition performance to students' level of PBL group interaction: Are students learning during PBL group? *Journal of Dental Education, 75*(5), 653–664.

Schmidt, H. G. (1983). Problem-based learning: Rationale and description. *Medical Education, 17*, 11–16.

Spering, M., Wagener, D., & Funke, J. (2005). Brief report: The role of emotions in complex problem-solving. *Cognition and Emotion, 19*(8), 1252–1261.

Sugrue, B. (1995). A theory-based framework for assessing domain-specific problem-solving ability. *Educational Measurement: Issues and Practice, 14*(3), 32–35.

Tawfik, A. A., Trueman, R. J., Lorz, M. M., (2013). Design a PBL environment using the 3C3R method. *International Journal of Designs for Learning, 4*(1), 11–24.

Torp, L., & Sage, S. (1998). *Problems as possibilities: Problem-based learning for K–12 education*. Alexandria, VA: Association for Supervision and Curriculum Development.

Wood, P. K. (1983). Inquiring systems and problem structure: Implications for cognitive development. *Human Development, 26*, 249–265.

Wood, P. K. (1985). *A statistical examination of necessary but not sufficient antecedents of problem solving behavior*. Doctoral dissertation, University of Minnesota, Minneapolis, MN.

Xue, H., Qian J., Wang L., Yuan X., Chen Y., Wu W., Chen Y., & Sun K. (2013). 3C3R modified PBL pediatric teaching of Chinese medical students. *PLOS ONE, 8*(5), 1–9.

Woei Hung is currently a professor in the instructional design and technology program at the University of North Dakota. He received his PhD in information science and learning technology from the University of Missouri–Columbia. He is a former chair of the American Educational Research Association (AERA) Problem-based Education SIG. His research areas include problem-based learning, problem-solving, types and difficulty levels of problems, systems thinking and modeling, and concept mapping and formation. He received the 2006 Junior Faculty Mentee Award from the *Interdisciplinary Journal of Problem-Based Learning* for his 3C3R PBL problem design model paper and 2007 Outstanding Publication Award from AERA Division I for his coauthored paper "Learning to Troubleshoot: A New Theory-Based Design Architecture."