

PROBLEM BASED LEARNING FOR EPISTEMOLOGICAL COMPETENCE: THE KNOWLEDGE ACQUISITION PERSPECTIVES

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ABSTRACT

This article explores the potential of Problem Based Learning (PBL) for epistemological competence in an engineering education area. The main idea is to explore how the processes in PBL promote knowledge acquisition that lead to an individual deep content learning. A review has been done from theoretical and conceptual aspect, as well as supportive evidence from several empirical findings. Within this, knowledge is constructed from the basic knowledge of concepts, principles, and procedural knowledge with integration to previous knowledge and experiences. The concepts and principles are linked and integrated with each other, forming a procedural knowledge, which promotes deep content learning. However, supportive evidence from the recent research literature indicates inconclusive findings, which called for more studies to provide more empirical evidence to investigate the effectiveness of PBL on knowledge acquisitions.

Keywords: *Problem based learning; active learning; knowledge acquisition; problem solving; educational theory*

1. Introduction

Developing domain-specific knowledge involves the knowing and understanding of three key components such as concepts, principles, and procedures (Sugrue, 1995). The concepts and principles are known as declarative knowledge, which is “know-that”, while the knowledge of procedures is known as “know-why” or “know-how” (Winterton, Delamare-Le Deist and Stringgellow, 2005). Knowledge is critically important, particularly the knowledge of procedures, which will be converted into work practices at behavioural learning stage (Garvin, 1993). Declarative knowledge is important in promoting skills, where the concepts and principles are integrated and connected to each other in forming procedural knowledge (Sugrue, 1995; Winterton et al., 2005). In most educational practices such as in the traditional lecturing method, students’ learning may arrive at concepts and principles by rote memorization, but it may be difficult to arrive at deep content learning at highest procedural level, which influences an individual’s ability to apply knowledge (Winterton et al., 2005).

The move to a new pedagogical method, which is based on open-ended problems, real-world application, ill-structured, interdisciplinary, and students working in a small group that requires cooperation with group members and collaboration with experts, is seen as a possible way out to the issue discussed. All these adhere to PBL method that has great potential in fostering students’ learning to a higher level of procedural knowledge or deep content learning. As pinpointed by Savin-Baden (2000), PBL is best implemented for epistemological competence; students are expected to be competent in knowledge application and management in solving problem.

In this paper, the investigation focuses on how PBL processes promote students for better knowledge acquisition from theoretical and conceptual aspect. The links between PBL instructional methods and knowledge development are explored, as well as evidences on the potential of PBL in inculcating students with better knowledge acquisition are summarized. Finally, the future direction of the study is then formulated.

2. Problem Based Learning

PBL is an innovative teaching and learning method that resulted from the process of working towards the understanding or resolving a problem (Barrows & Tamblyn, 1980). It was originally introduced in the McMaster University in Canada as a method to teach physicians in medical education, in 1965. This method was initiated due to the students’ unsatisfactory clinical performance, particularly when dealing with real patients. Thus, students were presented with real-world problem scenarios and they had to answer a series of question, in order to engage them in a real learning process. Soon after that, the method was proven effective and in 1974, the McMaster medical school PBL model was established. This model inspired other universities to implement a similar design into their medical curriculum. Since then, PBL has been widely used in several higher educational institutions across the world, such as in China, Australia, and Denmark (Zhang, 2002; Brodie & Gibbings, 2007; Kolmos et al., 2007).

PBL operates in several major steps, as in the “Seven-jump” model (Maastricht PBL model), which can be summarized into three steps, which are; initial stage, PBL stage, and final stage. The first activity in the first stage involves a group formation, either by administratively or randomly assigning students into a small group during the first meeting session. The group is then presented with a PBL problem and they begin to analyse and understand the problem (Hmelo-Silver, 2004). Amongst the specific activities in this stage include formulating learning objectives (Schmidt 1993), identifying knowledge gaps (Barrows & Tamblyn, 1980), generating hypotheses (Hmelo-Silver, 2004), defining the learning issues and the concepts to be learned (Hmelo-Silver, 2004). These processes are mostly done by defining “what to know” and “what they know”, and further “what they need to know”. Within this, the teacher acts as facilitator to guide students’ learning through the PBL process cycle (Hmelo-Silver, 2004).

The PBL stage begins with students performing an independent self-study (Schmidt, 1993; Wee, 2004). They are expected to master both the knowledge and relevant information that may be useful in order to propose a solution. During the next meeting, a group discussion takes place and involves a specific decision making method through brainstorming session (Wee, 2004). They exchange and share their information (Schmidt, 1993; Wee, 2004), and with all the learning issues and hypotheses should reach an acceptable definition that is agreed upon by all members. The tutor is responsible for monitoring the group's progress through several methods including direct observation and formative assessment (O'Grady & Alwis, 2002). The direct observation method, may involve coaching roles such as probing and questioning, in order to trigger students' meta-cognition (Wee, 2004). Facilitator is responsible for providing feedback during formative assessment (Woods, 2000), and always encouraging students to keep up with self assessment in order to monitor their own progress and performance in problem solving (Barrows & Tamblyn, 1980; Woods, 2000).

In the final stage, students perform some preparation for a project presentation and assessment during the last meeting session. The problem solution is partially presented by each group member. Within this, they are evaluated based on group presentation, but the grading is based on individual marks (Kolmos & Holgaard, 2007). In some cases, the peer assessment is used to modify the group's mark; leading to awarding students with an individual grades (Lennox, 2003).

As feedback comes with formative assessment, the summative assessment also provides information regarding students' performance (Barrows & Wee, 2007). Besides awarding a grade, the summative assessment contributes to students' knowledge and skills development for the whole learning process. The feedback process also enhances students' learning through self reflection (O'Grady & Alwis, 2002). In general, the extensive assessment process, in the PBL final stage, is to measure how much students have learned in a particular area, and in the same time to encourage students to explore more within their niche area of expertise.

3. PBL and knowledge acquisition: Theoretical and conceptual perspectives

Based on three major theories in education, many sub-theories have evolved to explain human learning. In PBL processes, the step by steps learning processes are grounded by these sub-theories that explain how an individual engages in the learning process and thus enrich their knowledge acquisition. These include the theories such as the Contextual Learning Theory, Discovery and Inquiry Learning, Information Processing, Cooperative Learning, and Self-Determination Theory (Albanese, 2000; Wee, 2004). With these theories, many author agreed that the principle of instructions from the Constructivist Learning Theory offers the most relevant explanation in relating PBL with educational theory (Savery & Duffy, 2001; Hmelo-Silver, 2004; Kolmos et al., 2007).

In this context, learning occurs from three primary principles (Savery & Duffy, 2001); firstly, learning by a means of gaining an understanding in a holistic process through interaction with the environment; secondly, learning is being stimulated by the cognitive conflict; and thirdly, learning in terms of knowledge construction evolving through social interaction. The knowledge is not absolute but is constructed through interpretation of previous experience on an existing knowledge structure (Savery & Duffy, 2001). Savery & Duffy (2001) highlighted several instructional principles from constructivism, which are aligned with PBL instructional strategies. These principles are described as follows:

- Learning goal. Goals stimulate and engage learners in problem solving process. They are motivated to arrive at clearly defined goals.
- Problem generation. Real problem determines the concepts and principles within the domains to be learned; therefore the problem must be well crafted.
- Problem presentation. Problems engage students in authentic problem solving and they own the problem.
- Facilitator. The facilitators' prominent role is to promote higher order thinking skills and encourage independent and self directed learning.

Students are expected to develop their cognitive and actively engage in learning through PBL instructional strategies as according to these principles (Palincsar, 1998; Savery & Duffy, 2001; Hmelo-Silver, Duncan & Chinn, 2007). The cognitive development in this case, involves knowledge construction (Palincsar, 1998); whereas concepts and principles are learned through problem solving that is aimed at specific learning goals. Furthermore, the problem authenticity will promote students' ability to apply the concepts and principles learned (Savery & Duffy, 2001). According to Garvin (1993), students must first understand and use the new concepts that relevant to the specific goal. Then, the concepts are translated into new work practices in behavioural learning stage. Eventually, the knowledge and behavioural learning lead to visible performance improvements of an individual. Knowledge is actually being converted to skills, when the development reaches to a certain higher level of performance or competency (Winterton et al., 2005).

However, in achieving a higher level of knowledge performance and competency, one should first understand these basic components (Winterton et al., 2005). Understanding in a more holistic process and context requires students to experience a process of gaining knowledge through performing tasks (Hmelo-Silver, 2004). Within this, students engage in deep content knowledge acquisition, which is in light with one of the PBL intended learning outcomes (Hmelo-Silver, 2004).

In a PBL method, the format and design of the problem determines the students' knowledge acquisitions, in terms of concepts, principles, and procedural knowledge (Wee, Kek & Sim, 2001). The other components such as the role of the tutor (Wee et al., 2001; Wee, 2004) and the assessment strategy (Gijbels et al., 2005) serve as a supportive element on students' knowledge acquisitions. Recent research indicates that students taught in a PBL environment are capable of acquiring the knowledge taught and have a better structured mind and thus becomes more achievable in the future (Gijbels et al., 2005).

4. PBL and knowledge acquisition: Empirical evidence

The link between PBL and knowledge acquisition has been explored by looking into empirical research conducted in experimental and controlled conditions, as well as research which compared both PBL and traditional lecturing approach. In order to cover the most recent research, the articles selected focus on the studies conducted in the period 2000 to 2009. The articles selected also include several learning disciplines to broaden the scope, due to the limited number of studies that conducted within engineering education field.

This articulation is based on three levels of knowledge structures, which are; knowledge of concepts, knowledge of principles, and knowledge of procedures (applications) (Sugrue, 1995). The remainder of this section will first describe the effects of PBL on the knowledge of concepts and principles, and then describe the effects of PBL on knowledge of procedures or applications.

Based on the review, most of the studies measure the general content of knowledge without specifying into specific knowledge structures. Only a few of articles reported the three levels of knowledge of concepts, principles, and procedures. The majority of the studies indicate that PBL contributes positively on students' knowledge acquisition, in the aspects of concepts and principles (Capon & Kuhn, 2004; Bilgin, Senocak & Sozbilir, 2009; Mantri et al., 2009). On the other hand, several studies also indicate that PBL contributes equally as traditional learning approach on students' concepts and principles knowledge acquisition (Matthews, 2004; Dehkordi & Heydarnejad, 2008; Sendag & Odabas, 2009). These equivocal findings indicate that the effect of PBL on concepts and principles knowledge acquisition remain elusive across disciplines and populations, within higher educational context.

In a specific example, Bilgin, Senocak & Sozbilir (2009) investigated the effects of PBL on students' performance in Chemistry course. The Conceptual Gases Test and Quantitative Problem Gases Test instruments were used for pre-test and post-test to assess students' achievement. The Conceptual Gases Test requires students to master the concepts and principles, while the Quantitative Problem Gases Test requires students to manipulate the concepts and principles (i.e. application) taught. Both groups showed no significance in the Quantitative Problem Gases Test, but the experimental group scored higher in the

Conceptual Gases Test. Similarly in Polanco, Calderon & Delgado (2004), stating that the PBL students' academic achievement was significantly higher than their counterparts in traditional lecturing methods. The test instrument was adapted from previous studies, which was intended to assess students' concepts and principles acquisition.

The study by Mantri et al. (2009) has provided an insight into the effectiveness of PBL in Electronics Communication Engineering programme. The PBL students performed much better in the knowledge test that assessed engineering theoretical knowledge. The test was developed based on the Bloom's taxonomy; however, the specific analysis on each level was not reported. Findings in the work by Van den Bossche et al. (2001), the knowledge test was developed and used to measure students' declarative knowledge (i.e. concepts and principles). The result indicated that the PBL students outperformed their traditional counterparts on concepts and principles acquisition. Similarly in Capon & Kuhn (2004), the data comparison indicated positive effects on concepts acquisition, which was in favour of PBL students.

On the other hand, several studies indicated no changes in knowledge acquisition, whether students are treated with PBL or the traditional lecturing approach. It is difficult insight into specific effects of PBL on concepts and principles learning, since the studies did not provide specific explanation on this knowledge structure. This was supported by the study from Matthews (2004); the Engineering Graphics knowledge was assessed, however the specific components of the basic concepts and principles were not clearly explained. Nevertheless, the knowledge test of Engineering Graphic course, demonstrated no significant difference in both controlled and experimental groups. In Sanderson (2008), the recall questions from standardized instrument were used to measure students' knowledge. The author concluded that both groups were not significantly difference on knowledge acquisitions. The similar findings were also illustrated by several other studies, such as in Kasai, Sugimoto & Uchiyama (2006) and in Sendag & Odabas (2009).

Although, most of the studies reviewed indicate a tendency towards positive effects, more studies are needed to focus on the knowledge of applications. The studies that specifically examine the effects of PBL on this area are still scarce across different disciplines, and therefore the effectiveness of PBL to promote knowledge of applications seems remains inconclusive in any findings. The existing studies that reported PBL less effective in inculcating knowledge of applications (e.g. Van den Bossche et al., 2001; Matthews, 2004; Sanderson, 2008), are quite balanced with the studies that reported positive findings (e.g. Capon & Kuhn, 2004; Kasai, Sugimoto & Uchiyama, 2006; Dehkordi & Heydarnejad, 2008).

Specifically, Capon & Kuhn (2004) found that the PBL students possessed a high ability in relating to the concepts, understanding the meaning, and applying it to a specific case. Students who experienced PBL were found able to integrate and apply the two business concepts taught. In Kasai, Sugimoto & Uchiyama (2006), the knowledge applications that were measured by the essay test, indicated that the PBL students scored higher when compared to the traditional method students. This study was conducted in Physical Therapy education, which involved nine students in a PBL experimental group and eleven students in a controlled group. In other context of comparison, using the Bloom's taxonomy of cognitive domain, PBL students scored higher in multiple choice question tests that measured the knowledge of applications and evaluations, but not in understanding levels (Dehkordi & Heydarnejad, 2008).

The study that reported negative findings, Van den Bossche et al. (2001), indicated no effects on students' ability to apply knowledge in Macroeconomic course, when PBL was used as treatment. However, the details analysis on the case-based test revealed that the PBL students indicated a tendency to score higher at each level of expertise. Likewise, the study in Exercise and Sport Science, Sanderson (2008) found that students in PBL group did not increase their ability to apply knowledge. These similar findings also illustrated by Matthews (2004) study, whereby both groups performed at the same level in a Computer Aided Design (CAD) test, which measured the knowledge of applications and performance.

An insight into these knowledge structures is important, since PBL is theorized to promote deep content learning (Hmelo-Silver 2004; Belland, French and Etmer, 2009). In across disciplines and populations, the available evidence inclines to show that the students in traditional learning approach have better content knowledge acquisitions of concepts and principles compared to their PBL counterparts. When the Bloom's

taxonomy of cognitive domain becomes the comparison points, PBL appears to be effective in promoting students' learning at higher cognitive level, including application and evaluation.

The systematic reviews in medical field conclude that students in the PBL methods gained slightly less factual knowledge of concepts and principles (Dochy et al., 2003). In addition, there was no convincing evidence to support the PBL instructional approach improved students' knowledge and clinical performance (Colliver, 2000). Given the knowledge as the whole structures of concepts, principles, and procedures, the effect of PBL appears to be equivocal (Gijbel et al., 2005).

Generally, the studies that investigating PBL effectiveness in promoting students' deep content knowledge acquisition appears to be vague in findings even though there is a tendency towards positive effects on concepts and principles learning. Additionally, the effectiveness of PBL in fostering knowledge of application and performance is still scant. In regards to this context of literature review, systematic evidence is scarce and thus insufficient to be deemed conclusive. More studies are needed to provide more robust evidence on each structure of concepts, principles, and the application of concepts and principles. It is particularly the study that conducted in other disciplines and populations, in controlled and experimental condition, and uses reliable, valid, objective, and exact instrument, in order to generate more valid findings (Belland et al., 2009; Tan, Chye and Teo, 2009). The study must also concerns on the other variables threaten the experimentation, especially the possibility of the treatment diffusion between two groups of comparison (Maxwell and Delaney, 2004). Moreover, the PBL model used should clearly be explained, in terms of the sources and the purpose of the PBL inclusion, as pinpointed by Savin-Baden (2000).

5. Conclusion

Education in general, PBL appears as a potential tool for epistemological knowledge competence as pinpointed by Savin-Baden, in regards to Sugrue's framework of knowledge structure. In theory, the PBL method is believed to create an environment that conducive for deep content learning, which is believed to affect students' ability to apply knowledge. However, in this context of recent literature, existing evidences appear to be insufficient to strongly support the theoretical aspect, especially in engineering education field. The effectiveness of PBL in promoting students' deep content knowledge acquisition seems far from robust. This is due to the limited number of studies that scrutinize the link between PBL and include three levels of knowledge structure (concepts, principles, procedural). Therefore, more studies are needed to provide robust evidences through controlled and experimental study, and cares of the other real world variables, in order to increase the validity of study findings.

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