International Review of Social Sciences and Humanities
Vol.2, No.1 (2011), pp. 215-221
www.irssh.com
ISSN 2248-9010 (Online), ISSN 2250-0715 (Print)

The Effect of Problem Based Learning on Critical Thinking Ability: A Theoretical and Empirical Review

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(Received: 22-9-11/ Accepted: 18-10-11)

Abstract

Although, Problem Based Learning (PBL) has a strong theoretical supports from the literature, to date there has been many PBL research resulted with unexpected findings, leading to a conflict on the effect of PBL on students' critical thinking ability. In this review, the authors investigated the theoretical relation, as well as reviewed the recent empirical evidence on the effect of PBL on students' critical thinking ability. The review included the most recent experimental studies from multiple disciplines between the years 2000 to 2011. Within this, it is concluded that 1) the specific processes in PBL theoretically support students' critical thinking development according to the design applied, 2) empirical evidences in general are inconclusive in explaining the effect of PBL on students' critical thinking ability, particularly outside of medical field, 3) some evidences indicate that PBL requires long term exposure to foster students' critical thinking ability, 4) several predictors might also influence the relationship of PBL and critical thinking such as age, gender, academic achievement, and educational background.

Keywords: Problem based learning, engineering education, critical thinking, constructivist learning theory.

1. Introduction

Problem Based Learning (PBL) is a motivating, challenging, and enjoyable learning approach (Norman and Schmidt, 2000) that has resulted from the process of working towards understanding or resolving a problem (Barrows and Tamblyn, 1980). PBL was first introduced in the McMaster University in Canada in 1965. Soon after that, in 1974, the McMaster medical school PBL model was established. This model inspired other universities to implement a similar design into their curriculum. Since then, PBL has been popularized and used in several higher educational institutions across the world, such as in Australia, Denmark, and China (Kolmos et al., 2007).

Generally teaching critical thinking is the same important as for an individual is being educated (Norris, 1985). Some authors point that teaching critical thinking is about teaching students to appropriately use concepts, principles, and procedures, so that they are capable of producing fruitful outcomes and critical judgments (Bailin et al., 1999). Additionally, critical thinking has an important implication for transfer of knowledge and application of problem solving skills to novel situations (Garcia and Pintrich, 1992). In this capacity, several advantages for students learning are claimed for PBL to increase critical thinking ability.

Recent research has highlighted PBL effectiveness on targeted learning domains, such critical thinking ability (Sendaq and Odabas 2009; Iwaoka et al., 2010). However, other research has produced discouraging findings on these particular domains (Choi, 2004; Sulaiman, 2011). As a result, the existing findings of previous research have been inconclusive. Nevertheless, despite these equivocal evidences, PBL inclusion in higher education is continually being seen as acceptable in producing competence graduates; particularly in engineering education field. Therefore, in line with the most of educational institutions' campaign to improve the quality of teaching and learning, this study was designed to explore the effectiveness of PBL model, from theoretical and empirical context. The result, the review found several areas have unclearly been defined, and thus called for further research works.

2. The PBL Process

PBL operates in several major steps, as in the "Seven-jump" model (Maastricht PBL model). The steps can be summarized into three major stages namely; initial stage, PBL stage, and final stage (Masek and Yamin, 2010). In the first stage, the first activity involves a group formation, whether 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; the formulation of learning objectives (Schmidt, 1993), identifying knowledge gaps (Barrows and Tamblyn, 1980), generating hypotheses (Hmelo-Silver, 2004), defining the learning issues and the concepts to be learned (Hmelo-Silver, 2004), and this is mostly done by defining "what they know", "what they do not know" and further "what they need to know". In this case, 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). Students are expected to master the knowledge that relevant to the problem to be solved. Then, students conduct a group brainstorming and discussion session (Wee, 2004). They exchange and share their information (Schmidt, 1993; Wee, 2004) with all the learning issues and hypotheses should reach an acceptable definition that is agreed upon by all members. Meanwhile, the facilitator monitors the group's progress through direct observation and formative assessment (O'Grady and Alwis, 2002). The direct observation involves coaching roles such as probing and questioning, in order to trigger students' meta-cognition (Wee, 2004). The facilitator then provides feedback immediately after formative assessment (Woods, 2000) and always encourages students to keep up with self-assessment (Barrows and Tamblyn, 1980; Woods, 2000).

In the final stage, students prepares for a project presentation and assessment during the last meeting session. Students partially present their proposal of solution. The facilitator evaluates students' work based on either group or individual presentation (Kolmos and Holgaard, 2007). In some cases, peer assessment is used to modify the group's mark; leading to award students with an individual grades (Kolmos et al., 2007). Other methods of assessment are also employed in monitoring students' progress in learning (Barrows and Tamblyn, 1980).

3. PBL and Critical Thinking: Theoretical Perspectives

Critical thinking is in the family of higher order thinking skills, along with creative thinking, problem solving, and decision making (Facione, 1990). Critical and creative thinking are connected to each other, in producing an effective thinking and problem solving (Treffinger et al., 2006). Evidence suggests that the complex cognitive skills can be systematically taught (Jianzeng et al., 1997). For that reason, teaching higher order cognitive abilities such as critical thinking has always been the ultimate goal of education (Spendlove, 2008).

PBL is often theorized to promote students' higher order thinking skills, especially reasoning skills (Savery, 2006). PBL is anchored by Students Centered Learning approach that follows constructivist learning theory principles (Hmelo-Silver, 2004). In this context, knowledge acquisition becomes one of the prerequisites in developing students' critical thinking ability (Hmelo-Silver, 2004; Winterton et al., 2005). According to Winterton et al. (2005), knowledge and working memory play major roles in the acquisition of complex cognitive skills. This is particularly true because knowledge is operational and working within a social and attitudinal environment.

This in light with Ennis et al. (2005), points that critical thinking as a reasonable and reflective thinking that focuses on deciding what to believe or do. It is an analytical process of arriving at judgments that is directed by a specific end purpose to arrive at a logical, rational, and reasonable problem solution (Bailin et al., 1999; Facione, 2006). Some authors explain that critical thinking is the process of an individual taught to reason in improving the solution (Paul and Elder, 2003). Thus, the analytical process of reasoning must arrive at logical, rational, and reasonable judgments, within a given framework, and must agree with specific principles of thinking (Ennis, 1984), as proposed by Facione (2006):

(i) Analysis = identifying and examining ideas and arguments.
(ii) Inference = drawing conclusions.
(iii) Interpretation = clarifying meaning through categorization and translation.
(iv) Self-regulation = self-assessment and reflection.
(v) Explanation = justifying results, arguments or procedures.
(vi) Evaluation = assessing arguments.

In addition, critical thinking must match to the context (Norris, 1985) within a given framework (Bailin et al., 1999). In some other views, critical thinking matches with the value of an individual's judgment (Norris, 1985). This value of judgment may direct the students' response in regards to a certain specific context. However, when critical thinking is valued by the reasoning ability, then measuring critical thinking must include the general structure of reasoning ability, regardless of the context (Ennis, 1984). Moreover, according to Ennis (1984), it is important to examine the structure of reasoning, since the structure represents the general meaning of reasoning ability, based on what an individual's believes.

Based on the above conceptual definition, critical thinking ability is possibly nurtured by PBL, through the process of problem solving, particularly within group brainstorming sessions (O'Grady and Alwis, 2002; Wee, 2004). During these sessions, students critically consider one best possible solution for the problem at hand. The process is mediated by a facilitator, who is responsible for probing their meta-cognitive thinking, in making any decision (Wee, 2004). It is believed that probing questions may engage students in a systematic cognitive process that promotes the development of the students' reasoning ability. In addition, other processes, such as discussion, debating, sharing, and teaching one another, creates a platform for students to experience an environment that is conducive for critical thinking to grow (Schmidt, 1993; Wee, 2004). Similarly, students develop their critical thinking, especially reasoning skills through the process of interaction, reflection, and feedback in the problem solving or in the formative assessment process (Schmidt, 1993; Savery and Duffy, 2001).

Within this capacity, a strong basis exists that supports PBL's contribution to students' higher order thinking skills, especially critical thinking ability. The concept of "learning by doing" in the PBL approach is actually supported by Experiential Learning Theory, in which students learn thinking strategies by solving a problem (Hmelo-Silver, 2004). The facilitator then stimulates students' critical thinking in looking for a best solution, which is also in light with the concept of "scaffolding" from the Constructivist Learning Theory (Hmelo-Silver, 2004; Wee, 2004).

4. PBL and Critical Thinking: Empirical Evidence

This section summarizes the review of the recent studies that examined the effects of PBL on students' critical thinking ability. The review included the most recent experimental studies from multiple disciplines between the years 2000 to 2011. The result, in the first trawl of the recent PBL research, there was a gap in determining the effect of PBL on students' critical thinking ability. The existing results of previous research have been equivocal, so that available evidences were still inconclusive. Several studies that related PBL and critical thinking resulted with positive findings, especially in higher educational context. This was illustrated by Semerci (2006), in which the author studied the effects of PBL on critical thinking for students in the Professional Education Course. The comparison was in favour of the PBL group, students' critical thinking ability had increased after PBL treatment. The critical thinking was measured based on students' ability to focus and clarify the solutions, analyse, understand, and infer with self-regulatory judgment and assumptions. The author was using the self-developed questionnaire in measuring students' critical thinking ability.

The finding was supported by Sendaq and Odabas (2009) study; these authors had used an exact instrument in measuring students' critical thinking changes in PBL experiment. The result, students in PBL approach increased in their critical thinking ability compared to the students in the traditional learning approach. The critical thinking was measured using Watson Glaser Critical Thinking Appraisal (WGCTA), which is based on the ability in making inference, recognition of assumptions, deduction, interpretation, and evaluation of ideas.

Also, in Iwaoka et al. (2010), students in Food Science and Human Nutrition Courses indicated a significant increase in their critical thinking scores, which were measured using the Cornell Critical Thinking Test Specimen (CCTTS). This study was conducted without control group, the pre-test and post-test however were deployed to compare the significant gain in critical thinking for a single group of PBL treatment. The study was repeated eight times from 2001 to 2008 with different samples.

In studying a characteristic of critical thinkers, Derry et al. (2000) investigated the students' ability to scientifically and statistically to reason in problem solving in the University of Wisconsin-Madison. The interview processes were employed to assess students' reasoning skills, before and after the new statistical course implementation. Students worked in small groups in solving problems that were simulated based on real-world scenarios. They worked collaboratively with group members, while the tutor responsible in providing suitable instructional method and guidance to the respective groups. The post-interview showed that students improved their ability to reason statistically. This had clearly observed when students presented their problem solutions.

Tiwari et al. (2006) compared the effects of PBL and traditional learning approach on students' critical thinking ability for the undergraduate nursing programme in the University of Hong Kong. A longitudinal study was conducted, which involved a total of 40 students in the experimental group, who had undergone two semesters (one year) of PBL treatment. This study involved 39 students in the control group that were taught using traditional lecturing method. The data collected at four points of interval throughout three years of the course. The California Critical Thinking Dispositional Inventory (CCTDI) was used to measure students' critical thinking ability. The results, students in PBL had improved their critical thinking throughout the three years of the study. Interestingly, students perceived that PBL tutorial sessions had contributed to their critical thinking development.

On the other hands, several studies also resulted with negative findings or no significant difference of two groups' comparison in investigating the effects of PBL on students' critical thinking ability. This indicated by Polanco et al. (2004), PBL did not change the first and second year undergraduate students' critical thinking ability in Mexican universities. In this case, an integrated PBL module of Physics, Mathematics, and Computer Science were used in teaching students in engineering course. The California Critical Thinking Skills Test (CCTST) was used as the pre-test and post-test. The critical thinking changes were based on reasoning skills in making inference, including analysis, evaluation, deductive, and inductive reasoning.

Similarly, Choi (2004) studied the effect of PBL in Nursing Process Course. The result indicated that no significant difference between the pre-test and post-test data, for students' critical thinking aspect.

In Sulaiman's (2011) study, the results also indicated no significant difference for critical thinking, for both the control and the experimental groups. However, further analysis indicated that PBL students had better skills in making inference and assumption than the traditional method students. The study involved a sample from pre-service science teacher in the Malaysian context.

Beyond higher education context, the PBL instruction did not change the students' critical thinking ability in school level (Burris, 2005; Anderson, 2007). In Burris study, the author investigated the effect of PBL on critical thinking and content knowledge in secondary agricultural school. A total of 140 students were involved in the study, where 77 of them were treated with PBL method and 63 were using the conventional supervised method. The pre-test and post-test using WGCTA indicated no changes on students' critical thinking ability in regards of both methods of instructions. Similarly in Anderson study, the pre-test and post-test on 110 students in controlled and experimental group did not significantly different in their critical thinking ability. This study involved secondary students in Urban Agricultural Programme in the Chicago High School in the US.

In critical thinking studies, several predictors might influence an individual's critical thinking. These include gender (Rudd et al., 2000), age (Ennis at al., 2005), and academic achievement (Giancarlo and Facione, 2001). However, based on the studies reviewed, generally no relationship between age and critical thinking, gender role produces inconclusive findings, while academic achievement shows relationship on students' critical thinking ability.

In reviewing previous research, most studies compared two groups of samples using PBL versus traditional learning approach in controlled and experimental conditions, and used the pre-test and post-test results as a measurement. Only a few studies compared the result between pre-test and post test of a single group. Some studies also compared more than one control and treatment groups and compared the data of longitudinal study. In addition, fewer studies that conducted in two isolated locations, in order to control the possible treats of confounding variables. Within these, the author raised a serious concern; particularly the method of controlling extraneous variables and factors those might affect the quality of the research findings. These include the factors such as teacher effect, the module's design, the validity and reliability of instruments, the randomization of study samples, the gaps between the pre-test and post-test, and the possibility of treatment diffusion.

In regards to this context of literature review, generally PBL has a great potential to foster students' higher order thinking skills, especially critical thinking ability. The links between PBL and critical thinking ability outside of medical field are still lacking with substantial evidence to be deemed conclusive, especially from education point of views. This scarcity has called for more experimental studies that examine PBL effectiveness in different populations and disciplines. Therefore, the study on PBL and critical thinking remains equivocal and leads to inconclusive evidence. This review however provides some hints that PBL could be more effective in a long-term duration.

5. Conclusion

Based on the review, it is concluded that 1) the specific processes in PBL theoretically support students' critical thinking development according to the design applied, 2) empirical evidence in general is inconclusive in explaining the effect of PBL on students' critical thinking ability, especially the studies outside of medical field, 3) some evidence indicates that PBL requires a long term exposure to foster students' critical thinking ability, 4) several predictors might also influence the relationships of PBL and critical thinking such as age, gender, academic achievement, and educational background, which calls for further research work.

The implication is that, PBL curriculum must carefully be designed and concerned on the critical elements contributing to PBL effectiveness. This includes the roles of the facilitator in mediating students learning, particularly in triggering students' meta-cognitive thinking. With all these carefully considered, PBL may successful as what has been noted in the theory.

Acknowledgement

The author/authors would like to thank **Universiti Tun Hussein Onn Malaysia** for supporting this research under the Postgraduate Incentive Research Grant.

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