

PROBLEM-BASED LEARNING (PBL) IN MATHEMATICS: A META ANALYSIS

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INTRODUCTION

Mathematics is an interesting subject and can nurture creativity in life. However, students think that mathematics is an uninteresting and meaningless subject. Students feel afraid, worried and anxious to learn mathematics. Furthermore, students perceived that mathematics is a difficult subject due to lack of mathematics laboratory and unattractive teaching method that is not related to real life and real world problem (Ali et al., 2010; Cazzola, 2008). Moreover, many schools are more focused on their performance to achieve excellent examination results, especially in the public examination. As a result, students focus on the examination without understanding the concept of real mathematics. Previous research in mathematics shows that conventional strategy cannot enhance mathematical thinking skills (Ahmad et al., 2008) as nowadays, students like challenges in learning mathematics that emphasizes self-learning with available resources and help them to develop skills in various fields. However, they still need a teacher to facilitate them to identify what they need to know and learn in order to solve problems. Moreover, peers and computer-paper based cognitive tools (Schmidt et al., 2011) also play a significant role as a scaffold to facilitate meaningful and lifelong learning. Mathematics teacher should create a learning environment that makes

mathematics as an enjoyable subject that enhances students' thinking skills, brainstorming, as well as initiates more discussion and gives motivation. Students' perceptions towards mathematics as a subject that is not integrated and has no connection with real life can be changed by providing them with an authentic mathematical problem scenario, where this relationship between mathematical concepts and everyday life is often overlooked. PBL is a learning approach that uses latest issues in order to expose students with real world problems and their application in the workplace later on. PBL is also a group learning strategy where students with different levels (high and low) will help one another towards the construction of knowledge, in-depth understanding and generic skills such as teamwork, leadership, communication skills and motivation (Othman et al., 2010).

PBL started at the McMaster University in the late 1960s and spread widely to the North America and other countries (Abdullah et al., 2010; Albanese & Mitchell, 1993; Savery, 2006) in various fields including education (Sulaiman & Baco, 2012). PBL is an experiential learning that helps students to become active and meaningful learners. PBL provides students with real world problems to solve problems (Hmelo-Silver, 2004), promotes student-centered learning and enhances the development of students' higher-order thinking and fostering students' social skills (Azer, 2009). PBL has been implemented in various fields such as stated in the Table 1:-

Table 1 Implementation of PBL in various fields.

Discipline	Author
Science	(Inel & Balım, 2013; Liu et al., 2014; Drake & Long, 2009; Shahbodan et al., 2009; Wong & Day, 2009)
Geography	(Ratinen & Keinonen, 2011; Yeung, 2010)
Nursing	(Chan, 2013)
Physics	(Saka & Kumaş, 2009)
Biology	(Chin & Chia, 2004)
Business communication	(Pennell & Miles, 2009)

Architecture	(Javier & Cepeda, 2005)
Chemistry	(Peen & Arshad, 2014; Tarhan & Acar, 2007; Tarhan & Acar-sesen, 2013)
Leadership education	(Bridges & Hallinger, 1996)

This shows that PBL has been applied in medical as well as implemented in various fields which are science, geography, nursing, physics, biology, business communication, architecture, chemistry and leadership education. PBL uses ill-structured problem in the process of learning where there are multiple solutions and no one has the correct way to solve the problem (Chin & Chia, 2005). However, what about the application and impact of its implementation in mathematics? Moreover, learning in mathematics considers only one solution for the solving problems. Research should be conducted to study the potential use of PBL in learning Mathematics.

RESEARCH QUESTION

This paper aims to answer the following research question:
What is the impact of learning mathematics through PBL in primary, secondary and tertiary levels?

METHODOLOGY

Papers and abstracts that mentioned PBL as the title and keywords were retrieved. Papers that were retrieved were original and empirical published papers, as well as papers with the implementation of PBL in mathematics for students only. Review papers that had been published since 2008 until early 2014 were selected in this study. There may be exist limitation due to limited years, and relevant meta-analyses may have been missed. The procedure of this meta-analysis is based on the previous reviewed by (Dochy et al., (2003). The terms [problem-based learning], [Problem-based learning AND mathematics], [Problem-based

learning Primary mathematics], [Problem-based learning Secondary mathematics] and [PBL AND Mathematics] were used via databases such as EBSCOHost, IEEE*Explore* Digital Library, JSTOR, SAGE Journal, ScienceDirect, Taylor & Francis Online, Web of Science, ProQuest, Google Scholar and Interdisciplinary Journal of Problem-based learning.

However, the electronic search was not narrowed down and subsequent iterations were done manually to reduce the likelihood of introducing further bias at this stage. This was mainly because the participants' age group was often not or insufficiently reflected in the titles, keywords or abstracts. Following the initial selection on the basis of titles, the output of the electronic search included a total of 75 papers. We had found the implementation of PBL in mathematics for teachers and students. Majority of the papers were related to the implementation of PBL in medical education. The focus of these studies was only on the implementation of PBL in mathematics. 21 papers reported on the use of PBL concerning knowledge domain, result and level, which formed the final sample of papers. In this meta-analysis, the authors reviewed the literature based on the narrative review. A narrative view synthesized non-numeric data in the systematic way to know what we want to meta-analyze (Jerzembek & Murphy, 2013). The purpose of this meta-analysis is to review the implementation of PBL in mathematics. Table 2 shows a review of the implementation of PBL in mathematics.

Table 2 A review of the implementation of PBL in mathematics

Author	Knowledge domain	Results	Level
(Li, 2011)	Number	Most of the students got together and enjoyed the discussion Students' performance in the post implementation test was better than the post unit test	Primary
(Hatsaru & Küçükturan, 2009b)	Statistics	90% students thought the problem had an educational issue 90% students thought working in group increased their work and research abilities 80% students thought that mathematics is connected to real life 90% students believed that problem scenario was suitable for their grade	Secondary
(Happy et al., 2011)	Algebra	Cycle I - no improvement in critical and creative thinking. Cycle II - both showed improvement except for creative thinking in the aspect of fluency	Secondary
(Padmavathy & Mareesh, 2013)	Not Mentioned	Girls and boys attained better achievement	Secondary
(Kalaivani & Tarmizi, 2014)	Algebra	Enhanced conceptual knowledge of algebra. Ability to resolve high order thinking questions	Secondary
(Tarmizi et al., 2012)	Statistics	Improved students' overall performance, conceptual knowledge in learning statistics. Reduced number of errors and mental load in problem solving in statistics	Tertiary
(Ahmad et al., 2008)	Calculus	Increased level of confidence Retention of certain topics	Tertiary

Obviously, most of the studies report positive impact towards learning mathematics through PBL.

RESULTS AND DISCUSSION

The Impact of PBL in Primary Schools

From the meta-analysis, only 2 out of 21 papers that implemented PBL in primary level gave a positive impact in mathematics. Students can solve the problem in groups (Tillman, 2013). However, at the primary level, guidance from teachers is needed to lead students to work in groups (Li, 2011). Moreover, there are challenges and difficulties in implementing PBL at the primary level during the middle part of the intervention such as students' attitude and teachers' emotion (Li, 2011). PBL is a student-centered learning where students work collaboratively and are guided by teachers or lecturers as facilitators (Letchumanan, 2008). In PBL, students are encouraged to solve mathematical problems collaboratively rather than individually.

The Impact of PBL in Secondary Schools

From the meta-analysis, thirteen papers reviewed the PBL and how it was implemented within four weeks to one year to complete the task. From the review, PBL gave a positive impact to learning process at secondary levels. From the meta-analysis, PBL plays a significant role in creating cognitive and affective domain as stated in Table 3 :-

Table 3 Impact on cognitive and affective domain in learning mathematics through PBL.

Cognitive and affective domain	Author
Motivation	(Ali et al., 2011; Kohlhaas, 2011)
Belief	(Alfred et al., 2014)
Achievement	(Alfred et al., 2013; Kohlhaas, 2011; Padmavathy & Mareesh, 2013; Yahya, 2011)

Mathematical communication skills	(Abdullah et al., 2010; Tarmizi et al.,2010)
Group interactivity	(Hatisaru & Küçükturan, 2009a)
Permanent learning	(Hatisaru & Küçükturan, 2009a, 2009b)
Self-confidence	(Hatisaru & Küçükturan, 2009a, 2009b)
Active participation	(Hatisaru & Küçükturan, 2009a)
Teamwork	(Abdullah et al., 2010; Tarmizi et al., 2010)
Analytical thinking	(Hatisaru & Küçükturan, 2009b)
Cooperative	(Hatisaru & Küçükturan, 2009b; Yahya, 2011)
Problem solving	(Abdullah et al., 2010; Yahya & Zaman, 2008)
High-order thinking questions	(Kalaivani & Tarmizi, 2014)

Students enhance their knowledge (Kalaivani & Tarmizi, 2014) and mathematical concepts (Yahya & Zaman, 2008), and try to adopt new knowledge and experience by discovering through problems (Ali et al., 2011). From the meta-analysis, the researcher found a small number of research on creative thinking in mathematics through PBL. Moreover, there result shows that PBL is still lacking in creative thinking in the aspect of fluency (Happy et al.,2011). PBL allows students to gain experience and in-depth learning in mathematics, improves their problem solving skills and enhances metacognition and reasoning that provides students to be active in groups and motivation (Padmavathy & Mareesh, 2013). However, students at secondary level prefer the conventional method because they have learnt the basis from kindergarten. Moreover, there are challenges and difficulties in implementing PBL in secondary schools. Learning objective can be achieved through correct problem scenario (Abdullah et al., 2010; Kalaivani & Tarmizi, 2014). Teachers should choose the correct problem scenario and “*trigger*” to be implemented in the class and guide students in the correct path. In addition, peers should play a significant role to encourage their peers to involve in the discussion.

From the meta-analysis, the algebra is still being studied. Students need interaction and questioning environment to improve students' performance in algebra such as collaborative learning, PBL and others (Şengül & Erdoğan, 2014). Students found it difficult to work with the abstract concepts. Students cannot understand because they cannot visualize the abstract (Strand & Mills, 2014). Moreover, form two students are still lack the conceptual understanding of algebraic expressions (Seng, 2010).

The Impact of PBL in Tertiary Level

From the meta-analysis, the knowledge domain only focused on statistics and calculus at the tertiary level, in which the students were able to revise what they had learnt in previous knowledge. At tertiary level, PBL gives a positive impact on problem solving, effective verbal and communication skills, collaborative (Tarmizi & Bayat, 2012; Tarmizi et al., 2010), performance (Gürsul & Keser, 2009; Tarmizi et al., 2012), conceptual knowledge (Leppink et al., 2013), perceived value (Leppink et al., 2013), useful learning (Leppink et al., 2013), cooperation (Gürsul & Keser, 2009), retention (Ahmad et al., 2008) and confidence (Ahmad et al., 2008). However, more generic skills should be emphasized for future employment. PBL can offer an excellent platform for the development of generic skills (Baharom & Palaniandy, 2013). Moreover, students should be equipped with technical skills for the workplace. PBL can be integrated with the technology to be implemented as an innovation in learning (Tarmizi et al., 2012). Therefore, students will be ready with generic skills and technical skills in the working environment.

CONCLUSION

This study strived to ascertain the impact of PBL on mathematics knowledge domain, result and level. Research in PBL has been implemented widely. PBL gives a positive impact in research, especially in the medical field, as well as mathematics. Many researchers and

teachers stated that PBL is a solution in learning by understanding the concepts and application in real life. Students are involved in in-depth learning to construct the conceptual of knowledge and not just memorize knowledge (Yahya, 2011). The finding of this meta-analysis is consistent with other findings. However, the impact in other fields is higher rather than the impact in mathematics. In summary, the significant role of PBL learning in mathematics should be harnessed in multiple generic skills such as critical and creative thinking skills in order to enhance students with technology and facilities to understand the meaning of life, to survive and to carry out innovation in the 21st century.

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