

The Impacts of Implementing Problem-Based Learning (PBL) in Mathematics: A Review of Literature

Najihah Mustaffa, Zaleha Ismail, Zaidatun Tasir, & Mohd Nihra Haruzuan Mohamad Said

Kementerian Pendidikan Malaysia, Faculty of Education Universiti Teknologi Malaysia
Malaysia

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Abstract

Mathematics is a subject that relates to the real world and is applied in various fields. However, the teaching and learning of mathematics is more procedural and requires drill and practice. For this reason, students of mathematics become passive receivers who are unable to think mathematically. The literature indicates that Problem-based learning(PBL) is a student-centered approach that is able to stimulate students' thinking. Accordingly, the present study investigates the implementation of PBL at school level and the impact of learning mathematics through PBL in secondary schools. The analysis showed that PBL gave positive impact on the secondary school students in mathematics and the approach was found to be applicable in various knowledge domains in mathematics. However, teacher's role should be explored concurrently with the usage of ICT and the duration of PBL implementation should be considered based on the curriculum objectives, especially in algebra. The study concludes that PBL is able to enhance students' thinking and soft skill, which are necessary to fulfill the requirement of education in the twenty-first century.

Keywords: Mathematics, Problem-based Learning, Secondary school

Introduction

Mathematics can naturally help generate creativity and create an enjoyable environment as well as have learning flexibilities (Brunkalla, 2009). Mathematics can also play a significant role in representing, communicating and predicting events (Padmavathy & Mareesh, 2013). Learning mathematics requires the students to actively participate in constructing knowledge, and their grasp of it can lead to a more creative environment and quality of teaching. The knowledge gained will guide students to think about how to make changes for the betterment of society (Ali, Akhter, Shahzad, Sultana, & Ramzan, 2011). Mathematics are applied in many fields in the real world (Baki, Çatlıoğlu, Costu, & Birgin, 2009). However, the learning of mathematics tend to emphasize more on the procedural methods rather than allowing the students to think mathematically, thus making it difficult for the students to connect

mathematical concepts with the real world (Ginsburg & Amit, 2008; Macmath, Wallace, & Chi, 2009). In schools, students find mathematics difficult to grasp due to the lack of interesting teaching approaches, insufficient quality of mathematics teachers and limited mathematics laboratories (Ali, Hukamdad, Akhter, & Khan, 2010). Furthermore, the usual method of teaching and learning mathematics has led the students to become passive as teachers act as information providers, and they emphasize more on drilling the questions and rote learning than meaningful learning (Hatisaru & Küçükturan, 2009; Noor Liza, Wan Karomiah, Abdullah, & Yunita, 2011; Othman, Buntat, Sulaiman, Salleh, & Herawan, 2010). Therefore, the teaching and learning of mathematics should emphasize student-centered approach that requires them to construct their own knowledge and ability to think mathematically in school. Student-centered approach is rooted in constructivism which support several learning approaches including problem-based learning (PBL) approach (Gürsul & Keser, 2009; Macmath et al., 2009). Students are required to construct their own schema about associated mathematical ideas towards solving a problem. (Fatade, Mogari, & Arigbabu, 2013). Since the problem drive learning of mathematics, therefore students gain new knowledge before they can solve the problems given (Roh, 2003) by working collaboratively (Letchumanan, 2008). However, students still need teacher as a facilitator. to play a significant role in learning mathematics. Mathematics is an evolving science and a living subject that requires it to be explored. The role of teachers is to give the students the opportunity to discover mathematics in an exploratory way (Cazzola, 2008). Problem-based learning is the instructional approach that requires students to apply theory into practice which will lead to the construction of knowledge and skills through an ill-structured problem (Savery, 2006). In the mathematics classroom, PBL focuses on problem-solving and conceptual understanding (Fatade, Mogari, & Arigbabu, 2013). Unlike the conventional setting which emphasizes computational skills and solving the problems without understanding the concepts. Since PBL is not commonly practice in school setting, a comprehensive investigation on the impact of learning mathematics through problem-based learning in schools is necessary.

Research Questions

This paper aims to answer the following research questions:

1. How is the implementation of PBL in mathematics in school level?
2. What is the impact of learning mathematics through PBL in secondary schools?

Methodology

A review on literature was carried out to determine the impact of learning mathematics through PBL in secondary schools Papers and abstracts were retrieved based on the problem-based learning in the title, abstract or keywords. This synthesis review only focuses on problem-based learning in mathematics for primary and secondary schools, thus only published papers that provide original and empirical meta-analysis which focused its implementation on students were selected. The procedure of doing this synthesis review was based on the review of Dochy, Segers, Bossche, & Gijbels (2003). The terms [PBL AND Mathematics], [PBL Secondary and Mathematics], [PBL Primary and Mathematics] and [PBL] were used to conduct the search in EBSCOHost, Google Scholar, IEEE*Explore* Digital Library, JSTOR, SAGE Journal, ScienceDirect, Taylor & Francis Online, Web of Science and Interdisciplinary Journal Of PBL. Only papers which were published from 2004 until 2016 were selected. However, to reduce the likelihood of introducing bias at this stage, the electronic search was not narrowed down, and the subsequent iterations were done manually. One

difficulty arises as the participants' age group was often not or insufficiently reflected in titles, keywords or abstracts. The electronic search produced a total of 130 papers by using titles as the basis. Majority of the papers were classified under the implementation of PBL in various fields especially in medical education and science that required experiments to be done in labs. Since the focus of this study is to analyse the implementation of PBL in mathematics for schools only, the initial output from the electronic search was further screened. Finally, twenty-eight papers that matched our requirements were selected for synthesis review. In this synthesis review, the author reviewed the literature based on the narrative review. A narrative review synthesizes non-numeric data in a systematic way to identify the meta-analysis needed (Jerzembek & Murphy, 2013). The purpose of this synthesis review is to review the implementation of PBL in mathematics for schools level.

Table 1 shows the reviews of the implementation of PBL in mathematics in secondary schools

Author	Knowledge Domain	Duration of implementation	Result
(Cerezo, 2004)	Area, perimeter,	Not mentioned	Better group participants They students enjoy learning and belief success for students' at-risk through problem-based learning Able to apply knowledge in real life Increased self-efficacy of students
(Clarke, Breed, & Fraser, 2004)	Algebra	1 year	Feel positive in mathematics class Improvement in score for IMP students IMP girl students have positive outcome
(Yahya & Zaman, 2007)	Set	2 weeks	The students have the type of thinking which are Hypothetical Deductive (HD) and Empirical Inductive (EI) of thinking
(Yahya & Zaman, 2008)	Set	Not mentioned	The usage of the courseware is effective for the students in learning mathematical concepts and solving problems
(Cotič & Zuljan, 2009)	Not mentioned	Not mentioned	Experimental Group students able to solve more difficult mathematical problems Experimental Group Students more confident in solving mathematical problems

			Experimental Group enjoy learning mathematics
(Hatisaru & Küçükturan 2009)	Statistics	2 weeks	90% of the students thought the problem had an educational issue 90% of the students thought working in groups increased their work and research abilities 80% of the students thought that mathematics is connected to real life 90% of the students believed that problem scenario was suitable for their grade
(Hatisaru & Küçükturan, 2009a)	Whole numbers and digital subjects	Not mentioned	Found efficiencies and the deficiencies of PBL method and increased their motivation to lessons when used in math lessons
(Ali et al., 2010)	Set Information handling Geometry	4 weeks	Better performance in problem-solving Difference between the achievement level is due to problem based strategy.
(Abdullah et al., 2010)	Statistics	6 weeks	PBL performed better than traditional group PBL is efficient as traditional PBL and traditional showed positive perception towards group work Mathematical communication for PBL is 8.00 compared to traditional 7.21
(Noer & M.Pd, 2011)	Space	Not mentioned	Highest score for cooperation Lowest score is questioning skills
(Ali et al., 2011)	Set Information handling Geometry	4 weeks	Motivated using problem solving achieved better than by rote method
(Yahya, 2011)	Set	Not mentioned	PBL have students of 20% HD and 80% IE and traditional have students of 19.2% HD and 80.8% IE

(Kohlhaas, 2011)	Not mentioned	15 February 213 May 2011 2 months 28 days	More interested in Mathematics after using problem based lessons Better attitude about mathematics and working groups
(Happy et al., 2011)	Algebra	August until December 2010 4 months	Cycle I - no improvement in critical and creative thinking. Cycle II - both showed improvement except for creative thinking in the aspect of fluency
(Li, 2011)	Number	3 weeks	Most of the students got together and enjoyed the discussion Students' performance in the post implementation test was better than the post unit test
(Boone, 2013)	Algebra	Not mentioned	Do effect students' attitude through PBL Do change the students belief towards mathematics
(Ajai, Imoko, & I.O'kwu, 2013)	Algebra	Not mentioned	Higher performance compared to conventional method Efficacy of using PBL in enhancing the achievement in Algebra
(Tillman, 2013)	Not mentioned	2 years (Cohort)	Higher levels of working and helping their classmates compared to their peers in traditional, teacher directed instruction
(Fatade et al., 2013)	Indices and Logarithms, Algebraic Equations, and Series and Sequences.	3 months	Mean of post-test achievement on the TMT for the experimental class was higher (M=43.79) compared to mean of the control class (M=34.96). Post-test RDT achievement mean score for the experimental class (M=2.43) was higher than the mean score of the control class (M=1.34).
(Padmavathy & Mareesh, 2013)	Not mentioned	Not mentioned	Girls and boys attained better achievement

(Kalaivani & Tarmizi, 2014)	Algebra	Not mentioned	Enhanced conceptual knowledge of algebra. Ability to resolve high order thinking questions
(Fatade et al., 2014)	Indices and Logarithms, Algebraic Equations, and Series and Sequences	3 months	Post-treatment BFMQ mean score for the experimental class (M=3.44) was higher than the mean score of the control class (M=2.89) mean score showed the efficacy of the use of PBL in promoting students beliefs about further mathematics
(Ajai & Imoko, 2015)	Algebra	Not mentioned	Equal achievement for gender Female more retained knowledge compared male
(Adu & Olaoye, 2015)	Algebra	Not mentioned	Language proficiency does determine the achievement of the students Experimental group performance better as well as language proficiency Method of teaching does affect the achievement of Algebra
(Inpinit & Inprasit, 2016)	STEM	First semester of 2015	Learning using PBL with the STEM education concept could develop the students' mathematical conceptual understanding better than the traditional learning method, with .01 level significance
(Napitupulu, Suryadi, & Kusumah, 2016)	Trigonometry and Circle	Not mentioned	Facilitate the students getting their higher order thinking skills especially schools having middle or high ability students through PBL
(Botty, Shahrill, Jaidin, Li, & Chong, 2016)	Time & Currency Exchange	Not mentioned	Develop teamwork skills through PBL Improvement in post-test especially in real life knowledge and syllabus-required knowledge however the students fail to connect prior knowledge.

(Zakariya, Ibrahim, & Adisa, 2016)	Not mentioned	4 weeks	Positive effects in academic achievement and positive effects on retention on students through PBL No significance different between mean score of girls and boys taught by PBL
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Most of the studies shows positive impact upon learning Mathematics through PBL in school and applied to specific domains of knowledge. The positive impact implies for both categories students which are female and male (Ajai & Imoko, 2015; Padmavathy & Mareesh.K, 2013; Zakariya et al., 2016). However, female students retained knowledge compared to male students. Subsequently, there are limitation of implementation due to time consuming and the role of teacher as a facilitator should be harnessed. More importantly the utilization of ICT should be improved in process of learning through PBL to engage students and promote various skills in line with the 21st century.

Results And Discussion

The impact of learning mathematics through PBL in secondary schools

From the review, PBL plays a significant role in developing cognitive and affective domain as well as skills in using computer and information technology in learning mathematics through PBL. Students are able to communicate well in groups and feel the usage of ICT is effective to increase the understanding of mathematical concepts. However, their level of thinking only enables the students to describe and order things rather than to explore or create hypothesis for each finding (Yahya & Zaman, 2008; Yahya, 2011). This is due to the fact that the teaching and learning of mathematics is more focused on problem-solving rather than thinking mathematically. Furthermore, there is still a lack of ICT usage for learning mathematics through PBL. Additionally, the combination of PBL with STEM able to develop mathematical conceptual understanding (Inpinit & Inprasit, 2016).

Most of the review mentions that learning mathematics through PBL allowed students to work in groups (Abdullah, Tarmizi, & Abu, 2010b; Botty et al., 2016; Hatisaru & Küçükturan, 2009; Hatisaru & Küçükturan, 2009a), and increased their confident level and motivation (Alfred O Fatade et al., 2014). However, there existed deficiencies among the group members, it was time consuming and less problem solving. Some of the group members were not cooperative. Moreover, the students felt that they were always behind compared to their other friends and the teachers did not play their role as facilitators (Hatisaru & Küçükturan, 2009a). The main factor of PBL is emphasized on the learning process not the final product or final solution. From this situation, the students also learnt how to control the situation when in groups and play their role as the students. Teachers should understand their role as the facilitator not as the information provider, therefore the students will learn, not to be taught.

From the review, it also showed that students have a positive impact in their achievement scores in learning mathematics (Alfred Olufemi Fatade et al., 2013; Kalaivani & Tarmizi, 2014; Padmavathy & Mareesh.K, 2013; Zakariya et al., 2016), their thinking skills through PBL (Happy et al., 2011; Kalaivani & Tarmizi, 2014) and retention (Zakariya et al., 2016).

Another essential point, PBL able to facilitate higher order thinking skills among middle or high ability students (Napitupulu et al., 2016). In PBL process, the students able to relate the real life knowledge and syllabus required knowledge however fail to connect with prior knowledge (Botty et al., 2016). According to Kalaivani and Tarmizi (2014) students performed better in algebra or lower thinking questions compared to higher thinking questions. This showed that PBL is able to foster the acquisition of knowledge and its applications in real life.

The implementation of learning mathematics through PBL in middle school

From the review, the duration of implementation of problem-based learning in mathematics at secondary level between 2 weeks (Yahya & Zaman, 2007) until 2 years (Tillman, 2013). This shows that PBL can be implemented in middle school either intermittent or lengthy, however it is depending on the objectives to be achieved and also the mathematical knowledge. For the knowledge domains in algebra are reviewed starting 2004 until 2016, however most knowledge domains in algebra were not mentioned the duration of the implementation. PBL have the obstacle in implementation due to time constraints because subject-based class period middle school and high school less than an hour long (Ertmer et al., 2009). However, from the reviewed, showed that there were positive impacts in implementation of problem-based learning in mathematics. Teacher played significant role successful implementation of PBL to provide various preparations compared to traditional approach (Botty et al., 2016; Xiuping, 2002).

Future Studies

The potential study of problem-based learning in mathematics through computers should be explored especially in domain of algebra. Algebra is important as a gatekeeper for entering university and applicable in work place (Cai & Knuth, 2011; Choike, 2000; Walkoe, 2013). Most of the findings emphasized on the effectiveness of the usage computers and focus on knowledge of domain in set. The study should extended to other knowledge of domain. Moreover, the usage of computer in learning mathematics through problem-based learning in respect to identify and developed the thinking level and skills should be considered. Furthermore, the potential role of teacher in implementing PBL should be explored concurrently with the usage of ICT.

Conclusion

These findings show the positive impact in learning mathematics through PBL in schools. Research on PBL has been widely implemented especially in the medical field. However, that is not the case in learning mathematics through PBL as well as being equipped with the necessary ICT in schools. Nowadays, the need for ICT in learning is important (Hack, 2013). According to Ginsburg and Amit (2008), students actually deal with mathematical ideas in daily life. However, due to formal education, the students can only memorize and apply their knowledge on a concrete level but cannot relate the mathematical concepts with real life. These leads to the question of how to teach mathematics effectively and relate it to real life. As a conclusion, PBL played an important role to enhance thinking with support from ICT with specific domain in mathematics. Therefore, learning mathematics in schools will become meaningful as well as allowing students to enhance their thinking skills.

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