The Application of Problem-Based Learning in Mathematics Education on Several South East Asia High Schools

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ABSTRACT

Problem-based learning (PBL) is a learning method based on the process between learning material to real life problems. The method has been widely applied and shown positive results on different subjects and education levels. In this paper, we discuss the application of PBL in mathematics education on several high schools in South East Asia countries, which include Indonesia, Thailand, Malaysia, Singapore, and Vietnam, considering that all of the countries had close cultural and geographical aspects. Researches on the application of PBL showed overall positive results to the high school mathematics education in all of the observed countries, with similar and distinctive objective and outcomes were found. In Indonesia, the application of PBL in mathematics education improve student’s learning activities aside from its positive contribution to the learning outcomes, while in Thailand, Malaysia, and Singapore, PBL contributes to the improvement of students’ higher-order thinking skills.

INTRODUCTION

Mathematics is a fundamental subject which plays important role in education. The mathematical understanding would provide foundation to learn other subjects, such as physics, biology, chemistry, or even subjects in social sciences. Akanmu and Fajemidagba (2013) mentioned that the mastery of mathematics would provide students the basic knowledge and skill for other important areas, especially the mastery of science and technology. The importance of mathematical knowledge then promotes a wide research on the mathematics education around the world, whether on teaching specific mathematical subjects, different educational levels, learning media, and etc. Among various learning methods, problem-based learning (PBL) has gained attention and popularity in mathematics education.
The PBL has been firstly applied in medical education by Barrows (1996), and gradually applied to educational studies of other scientific fields. The learning method could actually be traced as far way back to Plato and Socrates era, whom used a form of PBL by asking students to think, collect information for themselves, and discuss the obtained information at class by running after new information. However, the historical foundations of PBL is presented by Dewey who used the method in the form of interrogative education and apprenticeship (Sünbül, 2011).

Polya (1957) described that the student's problem-solving skills can be seen from their ability to: (1) understand the problem, (2) make plans, (3) implement the plan, and (4) recheck problem solving process again. In order to achieve those abilities, the PBL is integrated to the subjects. Barrows (1996) explained that the features of PBL should be: (1) Learning is learner-centered, (2) Learning takes place in small learner groups, (3) Teachers are facilitators and guides, (4) Problems organize students’ focus and apply learning, (5) Problems are means for improving problem solving skills, (6) New information is acquired by individual learning.

Since then, many researches were done to understand the application of PBL on mathematics education. PBL in secondary mathematics education became popular in 1990 and was adopted by the Illinois Mathematics and Science Academy (IMSA) as its learning programmes and curricula (Savin-Baden & Major, 2004). The application of PBL in mathematics education then become an interest and widely applied on globally. In this paper, we discuss the current application of PBL in mathematics education on several high schools in South East Asia countries, which include Indonesia, Thailand, Malaysia, Singapore, and Vietnam, considering that all of the countries had relatively similar cultural and geographical aspects.

METHODOLOGY

Problem-based learning (PBL) could be defined as an educational approach where learning is driven by real-world problems (Othman et al, 2013). One of the PBL characteristics is to provide a simulative real-life problem that likely to occur in real life, so that PBL could facilitate the students to perform connection process between learning material to real life problems. Early research by Delisle (1997) showed that PBL allows students to acquire new knowledge or solve problems in daily life. The application of PBL then become a major interest among researchers in mathematics education. Its importance is respected not only at the national level, but also at the international level (NCTM, 2000). Moreover, the problem-solving ability itself is not just a goal in mathematics education, but also something that is very meaningful in everyday life, considering that in the world of work, being a problem solver can provide various benefits (NCTM, 2000). In addition, increased problem-solving skills will improve student learning outcomes by themselves, and thus will advance the quality of mathematics education.

Balim (2009) stated that problem-solving ability is not only one of the main principles of science and technology, but also crucial to the progress of mathematics education itself. Students who were taught in traditional teacher-centered mathematics education are preoccupied by numerous exercises and equations that are of limited use in unfamiliar situations. In contrast, PBL provides students with opportunities to develop their abilities to adapt and change methods to fit new situations. Students in PBL environments typically have greater opportunity to learn mathematical processes associated with communication, representation, modelling, and reasoning (Smith, 1998; Erickson, 1999; Lubienski, 1999).
Clements et al (2002) explained that problem-solving and reasoning were integral parts of the mathematical knowledge. In PBL, problem becomes learning instrument, motivating students to learn as the focus is no longer for the sake of school but to real life problems (Culver, 2000). The problem-solving process has then become the fundamental and primary area in the educational research since the early 1980’s (Bayat & Tarmizi, 2010), and continuously assessed, applied and developed until today.

RESULT AND DISCUSSION
Mathematics Problem Based Learning in Indonesia

The application of PBL for mathematics education in Indonesia was done as an effort to help students in improving their mathematical problem-solving abilities. The assessment by Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) to the Indonesian student’s mathematical problem-solving abilities showed unsatisfying result, placed below the average of international mathematics problem-solving abilities (Wulandari et al, 2015).

Interestingly, the application of PBL in Indonesia not only showed better problem-solving ability of the students, but also supported several other learning factors as well. Research by Rustam et al (2017) revealed that the action through implementation of PBL model increased learning activities and problem-solving skills of mathematics students. Moreover, Kadir showed that problem-based activity is effective to improve the problem-solving ability of junior high school students in coastal areas (Kadir, 2009).

Research by Nurullita et al (2017) further elucidate the application of PBL in Indonesian high school, and added that PBL learning model can be done individually or in a social group. Their research showed the differences between PBL and conventional learning in Indonesia as presented in Table 1.

<table>
<thead>
<tr>
<th>Problem-Based Learning</th>
<th>Conventional Learning</th>
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<tr>
<td>Students are encouraged to be independent or autonomous.</td>
<td>Students only receive knowledge that given by the teacher.</td>
</tr>
<tr>
<td>Students are encouraged to have high thinking skills.</td>
<td>The truth about what knowledge is final and absolute.</td>
</tr>
<tr>
<td>Students could work as individuals and groups.</td>
<td>The students’ interaction is low.</td>
</tr>
<tr>
<td>Students are encouraged to communicate actively in learning.</td>
<td></td>
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<tr>
<td>Students could look at the problem of multi-dimensional and able to understand the deeper problem.</td>
<td></td>
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<tr>
<td>Students are able to think critically, creatively, had higher level thinking skills and scientifically.</td>
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</table>

Source: Nurullita et al (2017)

In their research, Nurullita et al (2017) measure the Indonesian students’ ability to solve a mathematical problem through four stages, which were problems understanding, planning
solutions, implement the plan and re-examine the obtained results. The learning activities were designed according to the characteristics and stages of the problem-based learning model, which enabled the emergence of indicators in problem solving.

During the learning activities, PBL encourages students to help each other, sharing, as well as respecting between different learning abilities possessed by each student. The results showed that the model of problem-based learning can provide a boost to the students to learn to be affecting an increasing mathematical problem-solving ability of students. Moreover, research by Kartikasari and Widjajanti (2017) showed that learning by PBL approach based on Gardner's multiple intelligences is effective in terms of student's achievement, the mathematical connection capability, and self-esteem of the students in Indonesia.

**Mathematics Problem Based Learning in Thailand**

In the past, Thai students were accustomed to gain knowledge through lectures from the teacher, which provided fewer self-regulated learning opportunities, such as setting goals, communicating with their teachers and peers, getting feedback, and adapting their own knowledge during learning (Suanpang & Petocz, 2006; Tsai, 2010). The condition thus affects its learning tradition and environment, which can be seen that Thai students were more accustomed to passive learning with less emphasis on self-regulated learning on mathematics (Park & Nuntrakune, 2013).

The approach to improve the condition has been done through various approaches, including the application of PBL for mathematics education. Promsawan and Katwibun (2017) adapted the PBL learning processes from Othman, Salleh, and Sulaiman’s study (2013). They proposed five steps in the PBL processes for Thai students, which include (1) introduction to the problem, (2) self-directed learning, (3) group meeting, (4) presentation and discussion, and (5) exercises. Their research showed that 11th grade Thai students in a PBL classroom demonstrated self-regulated learning as defined by Zimmerman and Campillo (2003), which include forethought, performance, and self-reflection.

Moreover, by using students’ self-regulation strategy (Cleary, 2006) and Teachers’ self-regulation strategy (Callan & Cleary, 2012), research by Promsawan and Katwibun (2017) found that the students’ mean scores in all phases of self-regulated learning were increased. The interviews with students showed that students’ reflections, and teachers’ notes showed that in the 2nd step of the PBL processes (self-directed learning), the forethought and performance phase were observable, and in the 4th step of the PBL processes (presentation and discussion), the students showed obvious expressions in the self-reflection phase.

Aside from increasing student’s self-regulated learning, the application of PBL on mathematics education of Thai high school students also contributes to the students’ critical thinking skills. Study by Siriwat and Katwibun (2017) explored students’ critical thinking in five steps of a mathematics PBL classroom. The findings revealed that PBL allowed students to express their critical thinking in all of the dimensions, noting that PBL encourages students to interpret the problem, gather needed information, identify possible solutions, evaluate options, and present conclusions (Roh, 2003). In addition, PBL also gave opportunities for the students to share and evaluate their thoughts and opinions in a group, giving its nature that requires an open exchange of ideas and engagement by all members of the group (Hmelo-Silver, 2004).
Moreover, research by Siriwat and Katwibun (2017) also showed that in PBL classroom, students showed the highest score in the explanation of issues dimension and the lowest score in the conclusions and related outcomes dimension. These results were compatible with AACU’s report (2017) which demonstrated that explaining of issues as the strength and drawing conclusion as the weakness of students. Furthermore, the results showed that the students also had difficulty in the student’s position dimension as they omitted available viewpoints and specified their position inadequately.

**Mathematics Problem Based Learning in Malaysia**

The current concern of mathematics education in Malaysia is on the student’s higher order thinking skills (HOTS) as written in the Malaysian Education Blueprint (MEB) 2013–2025 agenda. The MEB is expected to tackle the lacks of communication and problem-solving skill of graduates, as claimed by the Director of Students Affairs Development in the Ministry of Higher Education Malaysia, Professor Dr. Mohd Fauzi Ramlan (KOSMO, 2012). Problem-based learning (PBL) is one of the approaches that were applied to achieve the target by giving realistic, simulated real life problems. Several researches were then conducted to understand the application of PBL and its effect to students’ HOTS in Malaysia.

Research by Tarmizi et al (2010) elucidate that more than half of the Malaysian students (58%) taught in PBL-based learning like to learn in groups, and the other 40% preferred to learn in pairs. In term of their study approach, most students prefer case study approach (75%) and project approach (25%). During the learning process, nearly half of students (48%) prefer to learn through exchanging of ideas with others. Benefits of this approach as perceived by the students included the ability to discuss and correct their misunderstandings and strengthen development of transfer skills. Students stated that they felt more confident and independent and were therefore more willing to contribute to discussion. However, most students (84%) agreed that PBL approach requires them to do a lot of self-study and do a lot of research. Moreover, students’ responses showed seven positive themes, namely fun working in groups, learn to locating own information for understanding of concept, able to apply interesting/relevant calculus concepts, accepting different perspectives within group, a stimulating experience, opportunity to learn in flexible time and, able to learn in order to learn new concepts. Clearly, students in this approach enjoyed working in groups and recognize the various learning experience exposed during PBL.

Study by Fatimah et al (2018) shown the importance of implementing the PBL strategy on mathematics learning in Malaysia. Students who were exposed to the PBL strategy performed better in the post-tests compared to students in the conventional learning group. Besides, they also scored significantly higher in solving higher order thinking questions although there was no difference in solving the lower order thinking questions. Their research showed that mathematics teachers make a substantial change in their teaching approaches. The change needs to be taken carefully and deliberately so that the students will have both the opportunity and necessary support to become proficient in mathematics and worth to be applied.

Moreover, the study by Fatimah et al (2018) was carried out to determine the effects of problem-based learning strategy on students’ cognitive performance as seen from the overall test performance in solving higher order and lower order thinking questions, with the mid-year test scores were used as the covariate. A total of 62 female students (35 students in PBL strategy group and 27 students in conventional learning group) from two intact classes of in a selected school were randomly chosen. The results showed the students in the PBL strategy group performed significantly better than the conventional learning group in the overall test performance and also in solving the HOTS questions. For the overall test performance, the effect
was relatively small, while for solving the HOTS question, the effect was moderate. This implied the PBL strategy was effective in improving students’ HOTS in mathematics. These findings concurred with many other comparative studies on the effectiveness between the PBL strategy and traditional lecturing method on students’ performance. For example, studies done by Zakariya et al (2016), Inpinit and Inprasit (2016), Napitupulu et al (2016), Kalaivani and Tarmizi (2014) and Fatade et al (2013) gave similar conclusions. The findings demonstrated students in the PBL strategy group scored significantly higher than the students undergoing the conventional teacher-centered learning.

The positive results of PBL application in Malaysia were possible due to the characteristics of PBL, such as learning collaboratively in small groups, activating prior knowledge through group discussion, having a teacher to facilitate learning and having resources at hand to help them solve the given problem were in line with students’ cognitive architecture (Schmidt et al, 2006; Hmelo-Silver et al, 2007). Hence, PBL lessons can be designed to facilitate the learning of mathematics in both secondary schools and higher learning. However, a study by Abdullah et al (2017) showed that students in Malaysia still had poor performances in non-routine problem-solving skills. In addition, teachers rarely emphasised on non-routine problem solving in classrooms as well (Silver et al, 2005; Leikin & Levav-Waynberg, 2007). These findings echo those in Abdullah et al (2014) which showed that in Malaysia, the teachers’ skill in solving non-routine mathematical problems was found to be weak despite having a good knowledge about non-routine problem solving due to the lack of HOTS elements application to the students in the classroom.

In addition, study by Abdullah et al (2014) also considered metacognitive skills in solving non-routine mathematical problems with HOTS elements. The findings demonstrated that the students’ metacognitive skills in the non-routine mathematical problem solving were at a medium level. These findings are consistent with those found by Saemah (2004), who reported that there are still shortcomings in terms of metacognitive practice among weaker students. However, the metacognitive skills in the written work differ between very low and very high-performance students. Low-level students are considered to have limitations in solving non-routine mathematical problems. This is because non-routine problems do not have simple solutions at a first glance. Instead, they require a different reasoning and the use of certain heuristic strategies (Celebioglu et al, 2010).

Teaching and learning process in the classroom which emphasize on rote learning and too focused on the content cause students to memorize the knowledge learned, rather than to analyse and synthesize the exact meaning of the knowledge. In Malaysia, since they do not have deep understanding regarding the knowledge learned, it leads to reduce their ability to think critically as well as to solve complicated problems (Shakir, 2009). The improvement of PBL in mathematics education focused on metacognitive thinking skills were then suggested.

Mathematics Problem Based Learning in Singapore

In 1992, mathematical problem solving was made the primary goal of the school mathematics curriculum in Singapore. Since then, though the curriculum has been revised twice (in 2001 and 2007), mathematical problem solving has remained its primary goal. In figure 1,
the mathematics curriculum framework for Singapore schools is presented (Singapore Ministry of Education, 2006). The emphasis on mathematical problem solving was influenced by recommendations in documents such as An Agenda for Action (NCTM, 1980) and the Cockcroft Report (Cockcroft, 1982) from the United States and the United Kingdom respectively. The revised mathematics syllabus showed that problem solving skills remained as the central focus and listed as one of the general aims for mathematics education (Singapore Ministry of Education, 2007).

Since then, significant work had been done. Ng (2002) showed that the majority of problems found in primary mathematics textbooks used in Singapore were closed and routine problems. Fan and Zhu (2000) found that while the lower secondary textbooks provided students with a strong foundation in problem solving, more open-ended problems as well as authentic real-life problems could be included. A recent review of research by Foong (2009) on mathematical problem solving in Singapore indicated that the knowledge on problem-solving approaches and tasks used in the classroom, teachers’ beliefs and practices, and students’ problem-solving behaviours have grown.

Studies on teaching of problem solving in mathematics classrooms are relatively few in Singapore. The Centre for Research in Pedagogy and Practice (CRPP), National Institute of Education (NIE) carried out a core program, mainly targeting classroom practices across various subjects including mathematics at both primary and secondary levels through classroom observations. Yeo and Zhu (2005) used the data from 118 coded mathematics lessons from 18 Primary Five classes and 19 Secondary Three classes by using the Singapore Pedagogy Coding Scheme designed by the CRPP to explore the occurrence of higher order thinking in mathematics classrooms. In the study, the researchers mainly looked into types of classroom activities, source of authoritative knowledge, student produced work, depth of knowledge, knowledge criticism, and knowledge manipulation.

However, the research of PBL in Singapore were also done by assessing students’ textbook. Textbook analysis and classroom studies have shown that the vast majority of textbook tasks are well-structured tasks (Ng, 2002; Fan & Zhu, 2000) and classroom instruction is mostly teacher-led (Ho, 2007). Foong (2002) has found that teachers in Singapore tend to adopt the teaching for problem solving approach where the emphasis is learning mathematics content for the purpose of applying them to a wide range of situations. Case study by Ho (2007) on four primary-level teachers confirmed that with the call for a wider repertoire of teaching methods, in general, and of problem-solving instruction, in particular, is necessary for teachers to explore alternative pedagogies for mathematical problem-solving instruction. A number of dissertation studies also looked into the effects of using new teaching strategies on students’ development of problem solving. In general, significant improvement for the experimental group was observed (e.g., Ho, 1997). However, many of the studies were done on a small scale and the intervention was usually in a short period. Therefore, some changes may not be able to be observed or even occur. Moreover, although the immediate assessment showed the positive effects of the PBL teaching strategies on students’ learning, how long the effects could last is another important issue to be investigated in future.
Mathematics Problem Based Learning in Vietnam

The rapid development of science and technology requires a lot of innovation in education and training. In Vietnam, the way of teaching is much more different. In the past, instruction was focused on catching and understanding the knowledge of students, while the recent teaching focused on the development of students’ competency. Many new teaching methods are applied, including the teaching method of discovering and solving problems (Ngoc-Gian, 2019). The Vietnam Ministry of Education and Training has developed a general education program which mainly focused on knowledge and skill, the focus of this time’s reform is on the formation and development of learner’s competences necessary for life. In the list of competences, problem-solving is one of the core competences that the program aims to (Tang & Pham, 2017).

Researches on integrating problem-based learning of high school students in Vietnam has been continuously performed and showed positive results. Research by Tran (2012) on problem-solving capacity in mathematics to high school students showed remarkable results. Do and Le (2017) studied the application of the teaching method of problem-based learning in teaching similar triangular subjects (8th-grade math) in Middle Schools in Vietnam, while Phan and Nguyen (2017) developed a scale and set of tools to assess students’ problem-solving ability through project teaching. Research by Ngoc-Gian (2019) added that the application of problem-based learning showed better learning outcomes in teaching Cosines Geometry for high school students in Vietnam compared to traditional teacher centred teaching.
The radical and comprehensive renovation of education and training at all levels in Vietnam aims to meet the requirements of industrialization and modernization, dynamic systems of information in a knowledge-based economy, and international integration. In this renovation, fundamental changes were occurred in curricula design and textbook compilation (Danh, 2016). In the previous educational reform, modelling activities were under-emphasized in Vietnamese mathematics curricula and textbooks (Nguyen & Tran, 2013). However, the newly revised mathematics curricula have focused on important mathematical ideas and processes that promote students working with complex systems, such as investigating, conjecturing, justifying, representing, and explaining together with real life data and phenomena. As a result, modelling and problem solving have become core parts of the process of teaching mathematics at all educational levels (Danh, 2016).

In mathematical modelling, students are encouraged to look for situations in their real life and to pose the problems by making questions and formulating conjectures (Brown & Walter, 2005; Kang & Noh, 2012). The mathematical modelling became a tool that helps students to understand about application of the mathematical concepts because it requires students to apply mathematical knowledge into real life and to extend the concepts beyond rote learning (Dan & Xie, 2011; Galbraith et al., 2010; Lesh & Zawojewski, 2007; Kaiser & Stillman, 2015). Moreover, mathematical modelling has been considered as a new trend for research on problem solving in mathematics education (Lesh & Zawojewski, 2007; Kaiser, 2014).

In Vietnamese mathematics classrooms, the mathematics modelling was done by following seven-stage modelling process: (1) real-world problem, (2) make assumptions, (3) formulate mathematical problem, (4) solve the mathematical problem, (5) interpret the solution, (6) verify the model, (7) report, explain, predict (Danh, 2016). During the modelling process, the students encouraged to transfer among these steps such as understanding the realistic task, simplifying the task, mathematising, solving mathematical problems, interpreting results, and revising the model (Blum & Ferri, 2009; Kang & Noh, 2012).

The in-depth research on mathematics modelling on Vietnamese high school students was done by Danh (2016), and the research revealed that some barriers in applying this modelling method in the classroom linked to teachers’ teaching styles, beliefs and teaching skills. Moreover, the research also showed that modelling approach would provide students with a potential opportunity to connect mathematics knowledge in the classroom to their real life, school and society. Thus, contributes to modernizing the mathematics curricula and textbooks in Vietnam in which mathematical modelling as well as problem solving would be considered as students’ core competencies.

**CONCLUSION**

The application of problem-based learning (PBL) showed overall positive results to the high school mathematics education in all of the observed countries. Among several South East Asia countries observed in this paper, Singapore shown to be the first to include problem solving in the curricula and continues to develop PBL in order to achieve long terms results. In Indonesia, the application of PBL in mathematics education improve student’s learning activities, while in Thailand, improved critical thinking skills were shown. In Malaysia, the application of PBL was done to improve students’ higher-order thinking skills, and in Vietnam, PBL aimed to support the rapid development of science and technology.

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