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THE DEVELOPMENT OF CRITICAL THINKING SKILL IN MATHEMATICS THROUGH PROBLEM-BASED LEARNING IN YOUNG LEARNERS

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บทคัดย่อ

งานวิจัยฉบับนี้มีวัตถุประสงค์เพื่อเปรียบเทียบทักษะการคิดเชิงวิพากษ์ก่อนเรียนและหลังเรียนในวิชาคณิตศาสตร์โดยผ่านการเรียนรู้จากการแก้ไขโจทย์ปัญหา และศึกษาความคิดเห็นของนักเรียนที่มีต่อการใช้รูปแบบการคิดเชิงวิพากษ์ในวิชาคณิตศาสตร์ โดยใช้กลุ่มตัวอย่างคือนักเรียนโรงเรียนนานาชาติแองโกสิงคโปร์ ชั้นประถมศึกษาปีที่ 4 จำนวน 30 คน ประจำปีการศึกษา 2564-2565 ผู้วิจัยเก็บข้อมูลเชิงปริมาณและเชิงคุณภาพ โดยให้นักเรียนทดสอบก่อนการเรียน หลังจากนั้นใช้กระบวนการคิดเชิงวิพากษ์ในวิชาคณิตศาสตร์ระหว่างเรียนและทำการทดสอบหลังเรียนอีกครั้ง นำผลคะแนนการทดสอบก่อนและหลังเรียนมาเปรียบเทียบผลลัพธ์คือคะแนนค่าเฉลี่ยหลังการเรียนมีค่าเท่ากับ 7.26 และส่วนเบี่ยงเบนมาตรฐาน 1.11 และการทดสอบก่อนเรียนได้ผลเฉลี่ยคือ 4.26 และส่วนเบี่ยงเบนมาตรฐาน 1.11 ผลสัมฤทธิ์ของการทดสอบ ก่อน-หลัง เป็นที่น่าพอใจ อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.01 จากผลลัพธ์แสดงให้เห็นว่าการใช้กระบวนการคิดเชิงวิพากษ์ในวิชาคณิตศาสตร์ทำให้นักเรียนมีพัฒนาการที่ดีขึ้น และด้านความคิดเห็นของนักเรียนที่มีต่อการเรียนโดยใช้รูปแบบการคิดเชิงวิพากษ์ซึ่งผู้วิจัยใช้การสัมภาษณ์เป็นรายบุคคลรวมทั้งใช้การประเมินจากแบบสอบถามความคิดเห็นของนักเรียน ผลวิจัยพบว่านักเรียนมีความคิดเห็นเชิงบวกต่อการเรียนโดยการใช้วิธีคิดเชิงวิพากษ์ในวิชาคณิตศาสตร์ ดังนั้นแนวทางการเรียนรู้โดยใช้การคิดเชิงวิพากษ์ในวิชาคณิตศาสตร์จึงถือได้ว่าเป็นประโยชน์ในการเรียนรู้คณิตศาสตร์และพัฒนาทักษะการคิดเชิงวิพากษ์ของผู้เรียน

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Abstract

This research aimed to compare critical thinking skill in Mathematics through problem-based learning (PBL) in young learners before and after the treatment and examine young learners' opinion towards the use of problem-based learning to develop critical thinking skill in Mathematics. The sample group size consisted of 30 grade 4 students who enrolled in Anglo Singapore International School of campus 31 in the academic year 2021-2022. The students were given a pre-test to check for their mathematical problem-solving skills, and thereafter, underwent a treatment of PBL teaching approach. This was then followed by a post-test to compare the results of pre and post treatment. Mixed method research was used consisting of quantitative and qualitative data analysis. The result of each student was analyzed using a paired sample T-test. The mean score of the post-test ($\bar{x}$=7.26, SD=1.11) reflected a significant increase compared to that of the pre-test ($\bar{x}$=4.26, SD=1.11). The p-value of both pre and post test is 0.01 which indicated that the test was statistically significant. This suggested that the treatment using PBL learning approach yielded a positive the students' learning outcome. The students' responses on their opinion towards PBL were also collected using individual interview and 5-point Likert scale questionnaire. The findings revealed that the students displayed a positive opinion towards the usage of PBL. Thus, PBL learning approach may be considered fruitful in learning mathematics and developing critical thinking skills.

Keywords: Critical thinking, problem-based learning, group collaboration, student centered, model drawing, teaching strategies.

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Introduction

Critical thinking is deemed as one of the most sought of qualities in this new age knowledge economy. Our modern-day market is driven by rapid changing technology and knowledge. Individuals has to constantly keep up to these changes to stay ahead of their competitors. Our economy has an increasing demand for people with diversity in knowledge, and good analytical assessment skills to integrate into solving problems efficiently in workplaces. Developing professionals with critical thinking skills to identify and question planning is highly essential to move countries forward (Richmond, 2007). Countries that are equipped with a better education system to promote critical thinking as part of their curriculum is usually more developed in terms of infrastructures and economy, compared to countries with a more inferior education system.

Professionals in work organizations have to navigate their way around multiple streams of information and solve problems on the jobs using critical thinking. This phenomenon is described as human work is equal to knowledge work which requires the worker to 'gathering, organizing, analyzing and synthesizing of information' (Mack et al., 2001).

In Singapore, Mathematics is one of the core subjects to help students develop critical thinking skills. They do this by introducing problem-based learning (PBL) into the mathematics curriculum for students as early as grade one. Learning problem solving skills through PBLs is comparable to real life applied learning or situated learning scenarios (Cass et al., 2003). In these classrooms, the teacher acts as a cognitive guidance to coach students towards their goal. Problem-based learning as an instructional approach can help develop mathematical thinking skills, which in turn increases critical thinking and problem analysis skills. Educators have deemed that critical thinking is the most valuable skill leading to future academic success (Anderson, 2018).

Mathematics is taught with the objective of developing mental and cognitive processes that enhances logical thinking alongside with problem solving skills (Department of Basic Education, 2011). Under the vision in Thailand 4.0, critical thinking and problem-solving skills have become one of the most important and sort out skills in the new knowledge-based economy (Jones & Pimdee, 2017). In order for students to develop critical thinking skills, teachers should try to teach in a problem-solving environment that challenges students to think and reason with various context using their experiences (Banes, 2013).

In today's classrooms, majority of the teachers are teaching mathematics using the traditional teacher-centered method. This means that the delivery of lesson content is mainly from teacher to students, with minimum students' participation. Students are taught to use memorization and repeating techniques to master mathematics. Whereas compared to this, learning mathematics using PBL approach is considered a more modern way of teaching mathematics. However, most elementary teachers lack the experiences of where mathematics is learnt through problem solving activities. In addition, Thailand did not have the budget or enough incentive for research in this field to be carried out. Changes made to the mathematics curriculum in Thailand was based on research done in other countries. Therefore, the recommendations made by those researches might be unsuitable for it to be applied in Thailand. In addition, most Thai mathematics teachers lack the educational background preparation to adopt the programs that were recommended by the research. As a result, many mathematics teachers are facing problems as they feel that they are not adequately prepared to handle contemporary mathematics programs which are unfamiliar to Thai application.

Due to the circumstances mentioned above, the researcher carried out this research to investigate if the usage of problem-based learning teaching strategies will have a positive effect on young learners learning mathematics in Thailand. Problem-based learning (PBL) is an instructional method whereby students learn using facilitated problem solving (Hmelo-Silver, 2004, p. 235). The problem-based learning consists of posing a scenario, consisting of daily possible events that requires the students to analyze and evaluate the information given to them in able to solve it. It is the learner's responsibility to what is the problem posed, using the information provided and determine the steps to the solution. In this process, teachers act as facilitators to assist and prompt students in their critical thinking towards the solution (Banes, 2013).

In addition, teachers can allow learners to work in collaborative groups that allow discussion and the free flow of ideas on how to identify the critical information in a scenario, promoting active learning. Students can communicate reasoning and justification of their solutions amongst one another and see that there could be more than one way to solve a problem. By looking at the perspective of their peers, learners can also try to review different solution paths concept to see which ones are correct. Through this instructional method, learners are able to develop critical thinking skills and construct the knowledge of mathematics at a deeper and longer lasting level.

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Research Framework

For this research, the independent variables are the problem-based questions and activities to be given to the students, and the dependent variables are improving the student's logical and analytical skills towards solving a problem using mathematical skills. Another dependent is the perception towards the use of problem-based questions to help students grasp the concept of the mathematical at a deeper level.

Research objectives

1) To compare critical thinking skill in Mathematics through problem-based learning in young learners before and after the treatment.

2) To examine young learners' opinion towards the use of problem-based learning to develop critical thinking skill in Mathematics.

Scope of the study

1) Location of the study

The study was carried out in the campus in Bangkok city, around the area of Asoke-Sukhumvit consisting of students from nursery to grade 6.

2) Participants

The researcher was using a clustered random sampling method to select the students (30 students) out of the total of 50 grade four students, consisting of the students with mixed mathematics ability as well as genders. In this school, students were usually divided into three groups of proficiency; mainly high, medium and low ability students. Ten students were randomly picked out from each of the three groups to achieve the 30 students stated. Selection was heterogeneous and contained the same number of male and female students.

3) Timeframe

The study was carried out for four weeks from January 2022 to February 2022. Each week, the researcher taught daily lessons from Monday to Friday, and for a duration of 50 minutes to 1 hour 40 minutes depending on the daily teaching schedule.

Literature review

A critical thinker must possess the following elements; reasoning, questioning of purpose, assumptions, concepts, reasoning to conclusions and implications of consequences.

Critical thinking is not the acquisition of knowledge, but the analyzing and processing of information through the habit of intellectual commitment on using those skills to make and informed decision or reasonable conclusion (Scriven & Paul, 1987). All learners have the ability to think, but thinking alone can be prejudiced and biased, therefore higher level of thinking must be cultivated through nurturing (Duron et al., 2006). The child requires instruction on how to process information, and to apply knowledge in order to arrive at an outcome, be it a choice, or a solution to a problem scenario. In teaching of Mathematics, there are different approaches to impart problem solving skills. This is where an approach that utilizes activity-based learning can be used to promote critical thinking in young learners.

Thailand school students' critical thinking skills in mathematics

Mathematics is not a subject using memorization, but primarily requires understanding and application of concepts learnt, as well as reasoning skills in solving a mathematical problem. The competency to think critically in the process of solving mathematical problems is much needed. Mathematics and critical thinking are two inseparable components mainly as, mathematical problems can be solved by thinking critically and critical thinking can be nurtured by mathematics (Dewi, 2020). Therefore, it can be said that critical thinking skills have a crucial role in solving mathematical problems in elementary school.

Singapore's global reign in mathematics

There were many factors contributing to Singapore's global reign in mathematics (Leinwand & Ginsburg, 2007). Singapore's mathematics curriculum which involves problem-based learning is perceived as one of the most successful method of teaching mathematics and developing critical thinking. Drawing bar models is unique towards these word problems and students find it enjoyable as they are able to visualize the problem given to them and solve it.

How mathematics curriculum is related to critical thinking

Some of the skills needed to excel in mathematics are as given (Staff Development for Educators, 2009):

1) Classifying
2) Comparing
3) Sequencing
4) Analyzing of parts and wholes
5) Identifying relationships

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6) Induction and deduction

7) Visualization

These qualities mentioned above are actually very similar qualities of that to a critical thinker. In developing critical thinking and the skills to think, teachers should focus on the flow of thoughts, rather than the final answer towards the problem. Teachers and students have to accept that there is more than one way to determine an answer. This helps students decrease the anxiety towards mathematics, and increase the confidence in the ability to solve mathematical problems. Typically, students are only taught the concepts and mechanics of solving mathematics equations and questions. In contrast, problem-based learning goes beyond just practicing techniques and procedural conceptual skills required to be proficient in mathematics. Problem based learning nurtures development of successful collaboration, critical thinking/problem solving and self-management skills (Larmer, 2015). PBLs presented in class requires students to make use of prior knowledge and conceptual skillsets.

Importance of critical thinking

Critical thinking is the mental process that takes place in the decision-making process, by regulating and organizing of known information to resolve a problem (Fisher, 2011). The objective of critical thinking requires an individual to analyze and issue to make an informed judgment. Thailand 4.0 is an economic model that aims to free the country from several economic challenges that the country has been facing for the past few years. In the past, Thailand has placed emphasis on agriculture (Thailand 1.0), light industry (Thailand 2.0) followed by advanced industry (Thailand 3.0). Under the vision laid out for Thailand 4.0, critical thinking skills is one of the skillsets that is much sought for in this new knowledge-based economy. However, a recent study that evaluates logical thinking and analytical skills showed that out of 6,235 students from ten Thai provinces, the average final score was just 36.5% with only 2.09% passing the test (Rujivanarom, 2016). This poses as one of the obstacles for Thailand to transform into a knowledge-based economy. Plato, in his discussions of logic, has indicated that critical thinking is the mechanism that helps individuals find answers to their confusion and problems (Thayer-Bacon, 1998). It is believed that critical thinking with knowledge is located in the mind of the individual, rather than by teachers transmitting the information to students (Ornstein & Levine, 2006). In contrast to this theory, most Thai classroom teaching strategies are teacher-centered based, revolving around the teacher

transferring information to the students without much questions or discussions amongst the students.

Components and steps of critical thinking

The ability to think critically has been described as a fundamental life skill (Galinsky, 2010) with plenty of literatures describing in details the instructions, practices, and strategies in a classroom to help students improve academically. As students progress into higher levels, critical thinking skills, decision making skills, and information gathering has to be taught. Critical thinkers are able to evaluate situations and problems, and come up with a best solution that produces the most positive consequence. They should also be able to come up with alternative solutions and analyzing the impact of their decision before making it. The National Association for Media Literacy Education (2010) strongly advocates teaching of critical inquiry, and encourage learners to actively ask critical questions about the information they receive. The University of Leeds outlined several key factors in thinking critically. These are as listed:

1) Describing - defining clearly the subject of interest, what is the involved and where it took place.

2) Reflecting - consider other perspectives and any new information by these alternate perspectives.

3) Analyzing - explaining how something is, and how something is by comparing and contrasting.

4) Critiquing - isolating the weaknesses in argument and acknowledging its strength. Positioning of self should be neutral.

5) Reasoning - using cause and effect to display logical thinking. Presenting evidence that refutes or proves an argument.

6) Evaluating - comment on the scale of success or failure and the value of something at face.

The capability to analyze and adapt accordingly to new situations is the main essence of critical thinking. Critical thinking in the sense of reflective thinking is the questioning of status quo and that is both an emotional and intellectual component (Dewey, 1910). Students should thus be taught how to examine and reflect on what they have learnt. Dewey (1910) deemed skepticism, questioning and reflection essential for a learner to develop critical thinking.

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Problem based learning to develop critical thinking skills

Critical thinking skill is known to be imperative in preparing learners for their education in the higher years, as well as also their career in the future workforce (Bellanca, 2011). It is the cognitive process that functions in the decision-making process, organization of information, to be able to efficiently solve problems (Fisher, 2011). Allen and Cowdery (2014) stated that it is important to give students a chance to use their minds and apply the knowledge they have learnt through various ways of thinking. Developing critical thinking in a classroom calls for a shift from the traditional drilling and content practicing approach, to problem-based learning where learners can apply the learnt content, from isolating a single subject content to the integration of various subject contents across disciplines; focusing on the understanding of the process as a whole (Savery, 2009). This research is based on the foundation that critical thinking and problem-solving skills cannot be uncoupled, and that these life skills can be taught, practiced and nurtured through the guidance of the curriculum instructions and the teacher (Marina & Halpern, 2011).

Progressing learners towards critical thinking

Learning objectives

Objectives should be communicated clearly such that students are aware of what is expected of them. The activities conducted within the class, combined with the communicated objectives and assessment will lead to critical thinking amongst the learners (Duron et al., 2006). These objectives chosen should be relative to the thinking level in Bloom's taxonomy. Bloom's taxonomy is a model that is designed for educators to plan their lesson strategies and objectives.

Teaching learners through questioning

In order to foster understanding and stimulate cognitive development amongst students, educators must present argument and ask questions instead of reciting facts towards students. By focusing on activities and experiences which are linked to the lesson objectives, learners get to be more involve in the lesson, facilitating critical thoughts and perspectives all through the lesson (Smart & Csapo, 2007). These activities directly or indirectly enable students to relate to the lesson objectives, allowing them to engage in interactive questioning and discussion which lead to growth of critical thinking.

Reviewing and refining

Reviewing practices done by the students, and going through mistakes together reinforces the content learnt and uproot any misunderstanding of the concepts taught. Mistakes should always be reviewed so that the learner is aware what and why their assessment is wrong and how to do it correctly. Teachers should always be constructive and purposeful in their feedback towards students. Comments given should be informational, encouraging and quantitative. Student assessment also serves as feedback to a teacher's lesson, to check if the teacher had been effective in delivering the objectives of the curriculum.

Research methodology

In this research, the independent variable was the application of using PBL to teach mathematics including the problem-based questions and activities that were given to the students, and the dependent variables included the students' critical thinking skill and their opinion towards the use of PBL in learning Mathematics. The dependent variable was related to improving the student's logical and analytical skills towards solving a problem using mathematical skills. Another dependent variable was the students' opinion towards the use of problem-based questions to help them grasp the concept of the mathematical at a deeper level. The researcher issued a pre-test and a post-test, both consisting of similar questions of the same nature and level of difficulty but in a different order. This was to ensure that the test was being carried out in a fair and constant manner. Pre-test was administered before the 4 weeks of problem-based learning treatment and then a post-test was carried out after the treatment. Test results and student's opinions were then collected and analyzed.

As mentioned earlier, this research was conducted in one of the international schools in Asoke-Sukhumvit district of Bangkok, Thailand. The research school consisted of 3 classes of grade four with a total of 50 students in the academic year 2021-2022. The target group comprised of 30 grade four students comprising of mixed race and ability selected for the study.

The researcher adopted a mixed method design for this research. By "mixing" the qualitative and quantitative components together in one study, data elements are interlinked to yield a fuller account of the problem (Simons & Lathlean, 2010).

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Validity

Validity test is the measurement of how well a test measures what it is intended for. It refers to the degree in which the collected evidence and theory supports the interpretation of the test scores (Golafshani, 2003). In this research, the researcher utilized the index of Item Objective Congruence (IOC) which was developed by Rovinelli and Hambleton (1977) to measure the validity of the test. The range for IOC will be from -1 to +1.

All research instruments of this study were validated by 3 experts in education and all of them had long experience in Mathematics teaching. As a result, these instruments were validated with the score ranging from 0.67 to 1. This suggested that all of these instruments were accepted to be used for further data collection process and subsequently to achieve the research objectives.

Reliability

Reliability is the measurement of degree to conclude how consistent and stable the test is for the collected data. This is to check if the test carried out by the researcher was consistent over time and whether it could be replicable (Golafshani, 2003). For this research, the researcher was carrying out a KR-20 test; developed by Kuder-Richardson; to measure the reliability of the achievement test. A KR-20 test usually has a score of 0 to 1, given that 0 indicates no reliability and 1 indicating perfect reliability. A KR-20 score with a reading of 0.7 is generally considered to be reasonably consistent. The higher the score is; the higher reliability the item is. Any item that has a reliability lower than 0.7 would be automatically be adjusted or deleted and considered unreliable. In this study, all test items were reliable for the further study with the scores which were higher than 0.7.

Ethical consideration

To conduct this research in the school, the researcher was required to seek and obtained the approval from the principal of Anglo Singapore International Sukhumvit 31 and Ethics Human Research Board Committee**.** As the research was carried out with grade 4 students, individual teachers and department heads were also notified accordingly**.** Parents of the students involved were informed and notified as well**.** To comply with the ethics in human research, the researcher kept all personal information and bio data of the concerned students confidential throughout the study**.** All data was removed once the study was finished**.** As the researcher was both the primary investigator conducting the feedback interview with the participants as well as the teacher who taught in class, the research informed the participants

that there would not be any negative consequences or adverse effect for participants to express their thoughts freely.

Analysis and Discussion

The paired sample t-test is the pairing of the pre-test and post-test scores of the same student. This is to compare at different times, the before and after treatment effect on the same individual. The mean of the pre-test was 4.26 with a standard deviation of 1.11, and the mean of the post-test was 7.26 coincidentally generated the same sample deviation of 1.11. This means that the data from pre-test and post-test were distributed the same way around the means. The significant value (P value) obtained was 0.01 which is lower than 0.05. The T-score was 14.8, which indicates an increase of post-test scores from the pre-test scores. The difference in mean for the post-test and pre-test scores was a +3. This means that in general, participant's scores increased by an average of 3 points out of the full 10 points.

One Samples T-Test

	Mean	Sample size	Std. Deviation	Sig. level (P-value)
PRE-TEST	4.26	30	1.11	0.01
POST-TEST	7.26	30	1.11	0.01

Individual interview analysis

The interview was carried out with a total of 6 questions. Gathering information from individualized interviews enabled the researcher to obtain more detailed information and feedback from the participants compared to the survey questionnaire. Majority of the feedback was that participants enjoyed the PBL approach as they felt more involved during the lesson whilst taking part in group discussion within their groups. The participants also felt a sense of ownership towards their solutions as they were the one that came up with it through their group exploration. From the data gathered from the individual interview, the researcher was able to conclude that participants enjoyed the PBL teaching approach and some of the students even went on to do more math practices outside of class time.

Survey questionnaire analysis

The Likert scale was used consisting of a scale rating from 1 to 5, with 1 being "strongly disagree", 5 being "strongly agree" and score of 3 will be "neutral". From the questionnaire

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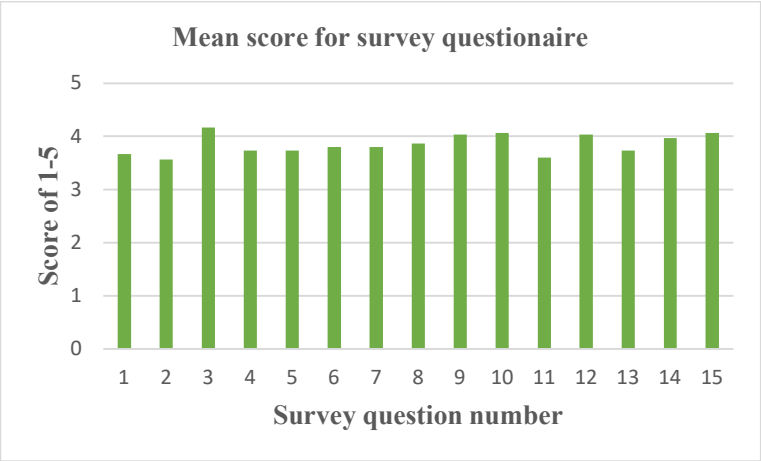
data collected, the researcher concluded the positive feedback towards PBL teaching method and that the majority of the participants were bending more towards “ agree” for the Likert scale survey questionnaire. From all findings, this would be possible to conclude that almost all the participants agree that PBL had a positive effect on them.



Discussion

As mentioned, this research had two major findings. The first finding was that PBL improved grade 4 students’ mathematical learning and critical thinking skills. The second finding was that the participants had positive opinion towards the use of PBL in classrooms.

Students’ achievement

Based on the result analysis, it was evident to conclude that PBL had a positive effect on the participants academically. All findings from the pre-test and post-test were reliable answers to the first research question. The results were similar to the research of Banes and Miller (2012) where they stated that the problem-solving ability of the experimental group that underwent PBL is significantly higher than the control group using traditional teacher centered learning.

Students’ opinion

Data from both the individual interview and survey analysis supports that the students enjoyed PBL learning and have positive perception towards it. PBL helped increased the students’ interests towards mathematics and helped them understood abstract contents with the aid of model drawings.

In conclusion, PBL had proved to be a fruitful tool to aid in the development of critical thinking in mathematics as well as nurture young minds to think and analyze problems critically. The research findings had proved that PBL learning provided a number of advantages over the traditional teaching and it was effective in promoting critical thinking skills. From all mentioned in this paper, it would be recommended that PBL should be utilized in mathematics teaching and learning for more effective students' learning outcomes as well as positive opinion towards mathematics learning.

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