Journal of Basic Education Research
Vol. 7, No. 3, May 2026, pp. 161~168
ISSN: 2716-3725, DOI: 10.37251/jber.v7i3.3042

Science, Technology, Engineering, and Mathematics-Based Problem-Based Learning Model for Fifth-Grade Students' Learning Outcomes in Perimeter and Area of Plane Figures

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Article Info

Article history:

Received Marc 4, 2026
Revised Apr 20, 2026
Accepted Apr 22, 2026
OnlineFirst May 20, 2026

Keywords:

Elementary School
Learning Outcomes
Perimeter and Area of Plane Figures
Problem-Based Learning
Quasi-Experimental Design

ABSTRACT

Purpose of the study: This study aims to analyze the effect of science, technology, engineering, and mathematics-based problem-based learning model on students' learning outcomes in perimeter and area of plane figures in fifth-grade elementary school. The study focuses on comparing learning outcomes between students taught using science, technology, engineering, and mathematics -based problem-based learning model and those taught using conventional learning methods.

Methodology: This study used a quantitative approach with a quasi-experimental method and nonequivalent control group design. The sample consisted of 49 fifth-grade students selected using purposive sampling. Data were collected using pre-test and post-test instruments. Data analysis was conducted using IBM SPSS Statistics 25, including normality, homogeneity, and Mann–Whitney U tests.

Main Findings: The results showed that the average post-test score of the experimental class was higher than the control class. The Mann–Whitney U test indicated a significance value of 0.013 < 0.05, showing a significant difference. This indicates that the science, technology, engineering, and mathematics -based PBL model has a significant effect on improving students' learning outcomes in mathematics.

Novelty/Originality of this study: This study highlights the application of science, technology, engineering, and mathematics-based PBL specifically on perimeter and area of plane figures in elementary school context. It provides empirical evidence of its effectiveness in improving learning outcomes and offers a contextual and student-centered learning approach, contributing to the development of innovative mathematics learning models at the primary education level.

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1. INTRODUCTION

Mathematics is a subject that plays a crucial role in developing logical, systematic, analytical, and critical thinking skills in elementary school students [1], [2]. Mathematics instruction emphasizes not only computational skills but also conceptual understanding and the application of these concepts in daily life [3], [4] . One of the fundamental topics that elementary school students must master is the perimeter and area of two-dimensional shapes, as this material is directly related to real-world activities, such as calculating floor area, measuring the perimeter of a yard, and drawing simple floor plans. Furthermore, mastery of two-dimensional shape concepts serves as the foundation for understanding geometry in subsequent educational levels.

However, students' mathematics learning outcomes in Indonesia still reveal serious issues. The 2022 Programme for International Student Assessment report indicates that Indonesian students' mathematics proficiency ranks 75th out of 81 countries with an average score of 366, still far below the Organisation for Economic Co-operation and Development average of 472. This situation indicates that the majority of students still struggle to understand and apply basic mathematical concepts. National Assessment results also show that elementary school students' numeracy skills remain in the basic category. This condition clearly indicates a significant problem in mathematics learning, particularly in students' ability to understand and apply basic mathematical concepts, including perimeter and area of two-dimensional shapes.

This issue was also observed among fifth-grade students in Cluster 03 of Gunung Tuleh Subdistrict. Daily assessment data on the topic of plane figures indicate that the average student achievement at public alementary cchool 04 Gunung Tuleh was 67.68, at public alementary cchool 06 Gunung Tuleh was 70.17, and at public alementary cchool 11 Gunung Tuleh was 69.75. These scores remain below the school's minimum competency standard of 75, indicating that the majority of students have not yet achieved mastery of the concepts of perimeter and area of two-dimensional shapes. These findings confirm that the problem of low mathematics learning outcomes is also evident at the local level and requires immediate instructional improvement.

Empirically, these low learning outcomes are linked to a teaching process that has not fully encouraged students to actively construct conceptual understanding [5], [6]. Observations and interviews reveal that instruction in some classes remains dominated by teacher-led explanations and problem-solving exercises, leading students to memorize formulas rather than deeply grasp the underlying concepts. Consequently, students struggle when faced with problems that differ from the examples provided. Although some teachers have attempted to relate the material to daily life and engage students through question-and-answer sessions and discussions, these activities have not been conducted consistently and have not fully guided students toward active problem-solving.

These conditions highlight the urgency of implementing a learning model capable of increasing student engagement, deepening conceptual understanding, and fostering students' ability to solve problems in a contextual manner. Therefore, selecting an appropriate learning model becomes a crucial step in addressing this issue effectively. One relevant model is Problem-Based Learning, as it is student-centered and emphasizes learning through real-world problems. In the context of mathematics education, problem-based learning enables students to construct knowledge through the process of investigating, analyzing, and discovering solutions [7], [8]. To make it more contextual, PBL can be integrated with a science, technology, engineering, and mathematics approach that combines elements of science, technology, engineering, and mathematics in learning activities based on real-world problems [9].

Theoretically, the implementation of science, technology, engineering, and mathematics-based problem-based learning can reinforce the constructivist view that knowledge is actively constructed by students through meaningful learning experiences [10]-[12]. This approach also supports the development of 21st-century skills, particularly critical thinking, problem-solving, collaboration, and the application of concepts in real-world situations [13]-[16]. Thus, research on STEM-based PBL is not only relevant for improving current student learning outcomes but is also crucial in contributing to the development of mathematics learning practices that are more adaptable to future needs.

A number of previous studies have shown that science, technology, engineering, and mathematics-based problem-based learning has a positive impact on student learning outcomes [17]-[18]. However, although previous studies have demonstrated the effectiveness of science, technology, engineering, and mathematics-based problem-based learning in improving students' learning outcomes, research that specifically focuses on its application to the topic of perimeter and area of two-dimensional shapes at the elementary school level remains limited. In addition, studies conducted in the context of fifth-grade students in Cluster 03 of Gunung Tuleh Subdistrict have not yet been reported. Therefore, this study aims to fill this research gap The novelty of this study lies in its investigation of the effect of STEM-based PBL on students' mathematics learning outcomes in a specific elementary mathematics topic, namely perimeter and area of two-dimensional shapes, at the fifth-grade level and within a local educational context that has not been previously explored.

Based on the above, this study aims to analyze the effect of the science, technology, engineering, and mathematics-based problem-based learning model on students' mathematics learning outcomes regarding the perimeter and area of two-dimensional shapes in fifth-grade elementary school. The results of this study are expected to strengthen theoretical findings regarding the effectiveness of problem-based learning integrated with STEM, while also providing practical contributions to teachers in designing mathematics instruction that is more active, contextual, and oriented toward current and future learning needs.

2. LITERATUR REVIEW

Mathematics learning outcomes in elementary schools are influenced by the quality of learning experiences obtained by students during the learning process [19], [20]. In the topic of perimeter and area of plane figures, students are not only required to master formulas, but also need to understand concepts, the relationships between elements of plane figures, and their application in real-life contexts [5]. From a constructivist perspective,

conceptual understanding will develop better when students are actively involved in constructing their knowledge through meaningful, contextual, and challenging learning experiences [21]. Therefore, mathematics learning requires an approach that is not only oriented toward final results, but also toward the process of thinking and problem-solving.

One model that is relevant to these needs is problem-based learning. Problem-based learning is a learning model that places real-world problems as the starting point of learning, encouraging students to investigate, discuss, develop ideas, and find solutions actively. This model is considered capable of improving students' critical thinking, problem-solving, communication, and collaboration skills [20]. In mathematics learning, PBL is also considered effective in shifting learning patterns from merely memorizing procedures to achieving deeper conceptual understanding. This finding is supported by systematic reviews showing that PBL in mathematics learning contributes to improving academic achievement, problem-solving skills, and students' cognitive learning outcomes [22]-[24] More broadly,.

However, the effectiveness of problem-based learning is largely determined by the context of the problems used and how well learning connects concepts with real-world situations [7]. In this regard, the science, technology, engineering, and mathematics approach becomes relevant to strengthen the implementation of PBL. Science, technology, engineering, and mathematics emphasizes the integration of science, technology, engineering, and mathematics in a unified learning experience, so that students do not learn concepts separately, but in an applied and contextual relationship [25]. Recent literature shows that integrated science, technology, engineering, and mathematics approaches are associated with improvements in learning outcomes, motivation, and higher-order thinking skills [26], [27]. In elementary mathematics learning, STEM integration provides opportunities for students to understand concepts more concretely through activities such as observing, measuring, designing, and solving problems related to their daily lives [17].

Based on this, the integration of problem-based learning and science, technology, engineering, and mathematics becomes a logical alternative solution to address the problem of low mathematics learning outcomes, particularly in the topic of perimeter and area of plane figures. The science, technology, engineering, and mathematics-based PBL model allows students to learn through authentic problems that require the active application of mathematical concepts, while also involving reasoning, exploration, and solution design [11]. In the context of perimeter and area topics, this model is relevant because students can connect concepts with real activities, such as measuring the length of objects, calculating surface areas, or designing simple shapes based on spatial needs. Thus, the solution chosen in this study is not only pedagogically innovative but also has a strong theoretical foundation.

Several previous studies support this approach. Ref. [10] reported that the implementation of STEM-based PBL can improve students' learning outcomes in mathematics. Ref. [28] also showed that the integration of science, technology, engineering, and mathematics -based PBL improves numeracy skills and makes learning more contextual. Furthermore, Ref. [11] found that the science, technology, engineering, and mathematics-based PBL model has a significant effect on elementary students' mathematics learning outcomes. More broadly, recent studies indicate that PBL interventions in mathematics are most frequently applied to geometry topics and are associated with improvements in learning outcomes and problem-solving skills [23], [29]. However, studies that specifically examine the effect of science, technology, engineering, and mathematics-based problem-based learning on learning outcomes in the topic of perimeter and area of plane figures in fifth-grade elementary school, especially in local contexts such as Cluster 03 Gunung Tuleh Subdistrict, are still limited.

Based on this review, it can be concluded that this study has strong justification. Theoretically, this study strengthens the use of STEM-based problem-based learning as an approach that aligns with contextual and student-centered mathematics learning. Empirically, this study is important to address the limitations of previous studies, particularly in the topic of perimeter and area of plane figures at the elementary school level. Thus, this study not only responds to the problem of low learning outcomes but also offers a relevant learning solution to support the development of critical thinking, problem-solving, and conceptual understanding in contemporary mathematics learning contexts.

3. RESEARCH METHOD

This study is a quantitative study using a quasi-experimental approach with a non-equivalent control group design [30], [31]. The quasi-experimental design was selected because the researcher could not randomly assign students to experimental and control groups due to the existing classroom structure. Therefore, intact classes were used to maintain the natural learning environment. This approach is commonly applied in educational research where randomization is not feasible and allows researchers to examine the effect of a treatment while preserving real classroom conditions. This design involves two groups: an experimental class and a control class [32], [33]. The experimental class received instruction using a STEM-based problem-based learning model, while the control class received conventional instruction. Both groups were administered pre-tests and post-tests to

determine the effect of implementing the STEM-based PBL model on students' mathematics learning outcomes regarding the perimeter and area of two-dimensional shapes [34].

Table 1. Research Design

Class	Pre-Test	Treatment	Post-Test
Experimental Class	O_1	X	O_2
Control Class	O_3	-	O_4

Notes:
X = Treatment using a PBL-based module integrated with STEM
\- = No treatment using a PBL-based module integrated with STEM
O_1 = Pre-test results of the experimental group before the treatment was given
O_2 = Post-test results of the experimental group after the treatment was given
O_3 = Pre-test results of the control group before the treatment was given
O_4 = Post-test results of the control group after the treatment was given

The subjects of this study were fifth-grade students of public elementary schools in Cluster 03, Gunung Tuleh District, Pasaman Barat Regency, in the 2025/2026 academic year. The population consisted of 67 students from three schools, namely SDN 04 Gunung Tuleh, SDN 06 Gunung Tuleh, and SDN 11 Gunung Tuleh. The sample was selected using a purposive sampling technique by considering the equivalence of students' initial abilities, student characteristics, and relatively comparable class sizes [35]. Based on these criteria, SDN 04 Gunung Tuleh was assigned as the experimental class with 25 students, while SDN 11 Gunung Tuleh was assigned as the control class with 24 students.

The research instrument used in this study was a mathematics learning outcome test on the topic of perimeter and area of plane figures, consisting of multiple-choice and essay questions. The instrument was administered to both groups in the form of a pre-test and post-test [36]. Before being used, the instrument was tested for validity, reliability, discriminating power, and difficulty level. The results showed that the instrument was feasible for use in the study, with a reliability coefficient of 0.839 for the multiple-choice items and 0.718 for the essay items, both of which were categorized as strong.

Table 2. Summary of Instrument Testing Results

Type of Item	Number of Items	Valid Items	Reliability	Category
Multiple-choice	10	6	0.839	Strong
Essay	5	4	0.718	Strong

The research data were collected using a testing technique, namely by administering a pre-test before the treatment and a post-test after the treatment to both groups [37]. The research procedure was carried out in three stages: preparation, implementation, and final stage. The preparation stage included preliminary observation, preparation of learning materials, and preparation and testing of the research instruments [38]. The implementation stage involved administering the pre-test to both classes, conducting learning activities using the STEM-based PBL model in the experimental class and conventional learning in the control class. The final stage involved administering the post-test, processing the data, and drawing conclusions based on the analysis results.

The data were analyzed using inferential statistics with the assistance of IBM SPSS Statistics 25. The data analysis techniques included the normality test using Shapiro–Wilk, the homogeneity test using Levene's Test, and the hypothesis test using the Mann–Whitney U Test. The Mann–Whitney U Test was used because the results of the normality test indicated that the data were not normally distributed. The testing was conducted at a significance level of 0.05 to determine whether there was an effect of the STEM-based PBL model on students' mathematics learning outcomes.

Table 3. Data Analysis Techniques

Analysis Stage	Technique/Test	Criteria
Normality test	Shapiro–Wilk	Sig. > 0.05 = normal
Homogeneity test	Levene's Test	Sig. > 0.05 = homogeneous
Hypothesis test	Mann–Whitney U Test	Sig. < 0.05 = significant

4. RESULTS AND DISCUSSION

This study was conducted from January 31 to February 9, 2026, in two sample classes, namely the experimental class and the control class. Before the treatment was administered, both classes were given a pre-test to determine the students' initial ability in the topic of perimeter and area of plane figures. Afterward, the

experimental class was taught using the STEM-based problem-based learning model, while the control class received conventional instruction. At the end of the learning process, both classes were given a post-test to measure students' learning outcomes after the treatment.

The descriptive analysis showed that the mean pre-test score of the experimental class was 22.9052, while that of the control class was 27.0783. After the treatment, the mean post-test score of the experimental class increased to 46.1764, whereas the control class reached 36.5488. These data indicate that the improvement in learning outcomes in the experimental class was higher than that in the control class.

Table 4. Summary of Pre-test and Post-test Results

Class	N	Pre-test	Post-test	Improvement
Experimental	25	22.9052	46.1764	23.2712
Control	24	27.0783	36.5488	9.4704

The prerequisite test results showed that the pre-test and post-test data in both classes were not normally distributed, but they had homogeneous variances. Therefore, the hypothesis was tested using the non-parametric Mann–Whitney U Test.

Table 5. Hypothesis Test Results

Test	Value
Mann–Whitney U	176.500
Wilcoxon W	476.500
Z	-2.496
Asymp. Sig. (2-tailed)	0.013

The significance value of 0.013 was lower than 0.05, indicating that there was a significant difference in learning outcomes between students in the experimental class and those in the control class. Thus, the STEM-based PBL model had a significant effect on fifth-grade elementary school students' learning outcomes in the topic of perimeter and area of plane figures. This result clearly answers the research problem, demonstrating that the STEM-based PBL model significantly improves students' learning outcomes. Therefore, the research hypothesis is accepted.

These findings indicate that learning through the STEM-based problem-based learning model was more effective than conventional instruction. This result can be explained by the characteristics of STEM-based problem-based learning, which place students in active learning situations through authentic and contextual problems. In the experimental class, students were actively involved in identifying problems, discussing, investigating, and formulating solutions to contextual problems. Such learning conditions are consistent with problem-based learning theory, which emphasizes active and strategic reasoning, collaboration, and the use of problems embedded in meaningful real-world contexts . This process helped students understand the concepts of perimeter and area of plane figures more meaningfully. The results are also in line with PBL theory, which emphasizes student-centered learning, as well as the STEM approach, which connects academic concepts with real-life situations [17], [10]. In this study, the STEM component was implemented by linking the concepts of perimeter and area to contextual activities, so that students were encouraged not only to apply formulas but also to relate mathematical ideas to everyday situations

In contrast, instruction in the control class tended to be teacher-centered, which limited student involvement in the learning process. Students mostly received explanations and worked on exercises without engaging in in-depth problem exploration. This condition caused the improvement in learning outcomes in the control class to be lower than that in the experimental class [39]-[41]. This finding supports previous research indicating that conventional learning environments tend to provide fewer opportunities for investigation, collaboration, and contextual problem-solving than STEM-oriented and problem-based approaches.

The results of this study are also consistent with previous studies showing that the implementation of STEM-based problem-based learning can improve students' mathematics learning outcomes. This study also extends previous findings by showing that such positive effects were identified specifically in the topic of perimeter and area of plane figures, at the fifth-grade elementary school level, and in a local context that has not been previously examined. Therefore, the STEM-based problem-based learning model can be considered an effective alternative for improving elementary school students' mathematics learning outcomes, particularly in the topic of perimeter and area of plane figures. However, this study has several limitations. The sample was limited to two classes in one cluster of schools, which may affect the generalizability of the findings. In addition, the duration of the implementation was relatively short, so it may not fully reflect the long-term impact of the STEM-based problem-based learning model. Other factors such as students' motivation, prior knowledge, and classroom conditions were also not fully controlled in this study. Accordingly, the findings of this study should be interpreted

with caution, and further research with broader samples, longer implementation periods, and tighter control of external variables is needed.

5. CONCLUSION

This study concludes that the implementation of the STEM-based problem-based learning model is effective in improving elementary school students' mathematics learning outcomes on the topic of perimeter and area of plane figures in fifth grade. This study aimed to analyze the effect of the STEM-based problem-based learning model on students' learning outcomes. The findings show that students who learned through the STEM-based PBL model achieved higher learning outcomes than those who learned through conventional instruction. These results are further supported by statistical testing, which indicated a significant effect of the implementation of the STEM-based problem-based learning model on students' learning outcomes. It can be concluded that the STEM-based problem-based learning model has a significant effect on improving students' learning outcomes. These findings are consistent with the view that problem-based learning integrated with the STEM approach can enhance student engagement, conceptual understanding, and problem-solving skills in a more meaningful way. Future research is recommended to apply the STEM-based problem-based learning model to other mathematics topics, involve a broader sample, and examine its long-term impact on the development of students' critical thinking, creativity, and problem-solving skills.

ACKNOWLEDGEMENTS

The author would like to express gratitude to the school principal, teachers, and fifth-grade students who supported the implementation of this research. The author also extends appreciation to the academic supervisor and colleagues for their support, suggestions, and encouragement throughout the research activities conducted in Cluster 03 Gunung Tuleh Elementary Schools.

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