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# The Effectiveness of the Problem-Based Learning Model on the Mathematical Problem-Solving Ability of Grade IX Students

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**ABSTRACT**

Mathematical problem-solving ability is important to develop in mathematics learning, but the ability of Grade IX students at SMP Negeri 2 Bukittinggi is still relatively low. This study aims to determine the development of students' mathematical problem-solving ability during learning with *Problem Based Learning* (PBL) and to determine whether this ability is better than that of students who received direct instruction. This study is a quasi-experimental study with a *nonequivalent posttest-only control group design*. The sample was selected using *purposive sampling*, namely class IX.7 as the experimental class (PBL) and class IX.8 as the control class (direct instruction) in the 2026/2027 academic year. Data were collected through quizzes over six meetings and a final test of mathematical problem-solving ability. The quiz analysis showed development of mathematical problem-solving ability in the experimental class from the first to the sixth meeting. The hypothesis test at the significance level 0.05 showed $P - value < \alpha$ so that $H_1$ is accepted. Thus, the mathematical problem-solving ability of students who learned with PBL is significantly better than that of students who received direct instruction.

**Keywords:** Mathematical Problem Solving; *Problem Based Learning*; Direct Instruction.

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## 1. INTRODUCTION

Mathematical problem-solving ability reflects students' competence in processing information, determining strategies, and obtaining solutions based on relevant mathematical concepts. NCTM (2000) includes problem solving as one of the main mathematical processes, together with communication, reasoning, connections, and representation. Mastery of this ability is also related to the need for 21st-century skills, which include the ability to think logically, critically, and systematically in solving everyday problems (Maharani et al., 2024; Wahyuni et al., 2024). In the national curriculum, problem-solving ability is also part of the objectives of mathematics learning as stated in the Learning Outcomes in the Decree of the Head of BSKAP Number 046/H/KR/2025 based on Minister of Primary and Secondary Education Regulation Number 13 of 2025 (BSKAP, 2025).

Lestari and Yudhanegara (2017) explain that this ability covers solving routine and non-routine problems, applied and non-applied. Sumarmo (2014) adds that the process involves complex cognition, namely understanding the problem, designing solution steps, and carrying out the planned strategy. This ability is measured through four indicators, namely (1) identifying the

known elements, the asked elements, and the adequacy of the information required; (2) formulating the problem into mathematical form or constructing a mathematical model; (3) applying formulas or mathematical models to solve the problem; and (4) explaining or interpreting the solution results (Batubara & Reflina, 2022).

However, Indonesia's achievement in mathematical problem-solving ability is not encouraging. The results of the Programme for International Student Assessment (PISA) show that Indonesia's average mathematics score declined from 379 in 2018 to 366 in 2022, and then to 364 in 2025. In PISA 2025, Indonesia ranked 78th out of 90 participating countries and economies, with a score still below the OECD average of 463. In addition, only 17% of Indonesian students reached at least Level 2, the basic level of mathematics proficiency, while the OECD average was 65% (OECD 2023, 2026). Yet PISA assesses the ability to formulate problems into mathematical form (*formulate*), to use concepts and procedures (*employ*), and to interpret and evaluate results (*interpret*) (OECD, 2018). At the national level, the results of the National Assessment for the junior high school level also show that students' numeracy achievement still needs attention. In 2024, 68.1% of junior high school students reached the minimum numeracy competence, while in 2025 the percentage was 62.53%, so the remainder had not met the expected standard (Kemendikdasmen, 2025). Studies at various educational levels show the same pattern. Sriwahyuni & Maryati (2022) reported that Grade IX junior high school students achieved only 19% on the data-sufficiency indicator, 56.25% on constructing mathematical models, and 62.50% on applying strategies and interpreting results. Andini and Yuanita (2025) found that Grade X students at SMA Negeri 12 Pekanbaru mastered only 11.22% at the interpreting-results stage, while Fitria & Sutirna (2024) recorded that only 13.89% of Grade VII students at SMP Negeri 5 Karawang Barat were in the high category.

A similar problem was found at SMP Negeri 2 Bukittinggi. Based on daily assessments from the Grade IX mathematics teacher, students generally could only solve routine problems, while problems requiring a problem-solving process could not be solved correctly. To obtain a clearer picture, the researcher gave a preliminary test to 289 Grade IX students consisting of three essay questions on the Pythagorean Theorem, developed from the four indicators of mathematical problem-solving ability (Batubara & Reflina, 2022). The results showed that the percentage of students who scored 0 increased from question 1 to question 3 on all indicators. On question 3, more than 60% of students scored 0 on every indicator, with the highest percentages on the indicator of explaining or interpreting results (91.00%), followed by formulating the mathematical model (85.47%) and applying formulas or models (79.93%). This shows that most students still have difficulty solving problem-solving questions on most indicators.

These difficulties are inseparable from classroom learning that still mostly uses the direct instruction model, in which the teacher explains the material and solution steps, gives examples, and then students work on routine practice problems whose steps are similar to the examples. This model limits students' active involvement because the learning process is dominated by the teacher (Lubis et al., 2024), so that students are less trained in analyzing problems and have difficulty when facing non-routine problems. One effort that can be made is to apply the *Problem Based Learning* (PBL) model. PBL is a student-centered approach that begins with presenting a contextual problem as the basis of learning activities (Tudjuka, 2025; Yulianti & Gunawan, 2019). Its main principle is the use of real problems to build knowledge while developing critical thinking and problem-solving skills (Shinta & Heleni, 2024). Applying PBL in mathematics learning can support students' mathematical problem-solving ability, even better than direct instruction (Armiati et al., 2018). According to Kemendikbud (2019), the PBL syntax consists of problem

orientation, organizing students, guiding investigation, developing and presenting work, and analyzing and evaluating the problem-solving process, which is in line with the problem-solving flow so that each stage supports the indicators of mathematical problem-solving ability (Ayari et al., 2025; Hidayat & Fitrini, 2025; Salsabila et al., 2024).

Several previous studies show that applying the *Problem Based Learning* (PBL) model has a positive impact on students' mathematical problem-solving ability (Syajidah et al., 2024; Yerizon et al., 2021). However, studies on the effectiveness of PBL are generally conducted through literature reviews or meta-analyses (Karlina & Mustika Sari, 2024; Novelia et al., 2023), or by combining PBL with other approaches, such as STEM and ethnomathematics (Radiah et al., 2024; Shongwe, 2024). Both tendencies leave limitations. Literature reviews and meta-analyses summarize findings from various contexts, so they do not directly describe students' achievement in classroom learning. Meanwhile, studies combining PBL with other approaches have not specifically examined the implementation of PBL without such a combination. Research that directly tests the effect of PBL by examining mathematical problem-solving ability based on the indicators proposed by Batubara and Reflina (2022) also still needs further study, particularly among Grade IX students at SMP Negeri 2 Bukittinggi. This study is important to obtain a picture of students' achievement on each indicator as well as their development during learning with PBL.

Therefore, this study aims to determine the development of the mathematical problem-solving ability of Grade IX students at SMP Negeri 2 Bukittinggi while learning with the PBL model. In addition, this study aims to test whether the mathematical problem-solving ability of students who learn using the PBL model is better than that of students who learn using the direct instruction model.

## 2. METHODS

This study is quantitative research of the descriptive and quasi-experimental (*quasi experiment*) type that applies a *posttest-only control group* design. Descriptive research was used to describe the development of mathematical problem-solving ability based on quiz results, while the quasi-experiment was used to compare students' ability based on final test results. The study was conducted over six meetings at SMP Negeri 2 Bukittinggi in the 2026/2027 academic year. The study involved 299 Grade IX students as the population. Before the sample was determined, prior ability across classes was analyzed. Because eight of the ten classes did not meet the normality assumption, testing was carried out using the *Kruskal–Wallis* test with the help of Minitab. The results showed a *P-value* < 0.001 at a significance level of 0.05, so there was a significant difference in medians among the classes tested. Therefore, the sample was selected through the *purposive sampling* technique, considering the learning schedule, students' characteristics, the similarity of the even-semester Final Summative Assessment scores, and the mathematics teacher's consideration. Based on these considerations, class IX.7 was designated as the group that followed *Problem Based Learning* (*PBL*) learning and class IX.8 as the group that followed direct instruction.

The learning in the experimental class followed the syntax of the Problem Based Learning (PBL) model. Each learning stage was linked to the indicators of mathematical problem-solving ability used in the study. The relationship between the PBL syntax and the indicators of mathematical problem-solving ability is presented in Table 1.

**Table 1.** Relationship Between the Syntax of *Problem Based Learning* and Problem-Solving Indicators

| **Syntax of the *Problem Based Learning Model*** | **Mathematical Problem-Solving Indicators** |
|---|---|
| Student orientation to the problem | Identifying the known elements, the asked elements, and the adequacy of the required elements |
| Organizing students for learning | |
| Guiding individual and group investigation | Formulating the mathematical problem or constructing a mathematical model |
| | Applying formulas or mathematical models to solve problems |
| Developing and presenting work | Explaining or interpreting the solution results |
| Analyzing and evaluating the problem-solving process | |

The research instruments consisted of quizzes and a final test. The quizzes were used to see students' development during the implementation of *PBL*, while the final test was used to measure mathematical problem-solving ability in both sample classes. Both instruments were developed based on the indicators of mathematical problem-solving ability proposed by Batubara and Reflina (2022). Before the final test was administered, the test was first tried out on Grade IX.A students at SMP Negeri 1 Bukittinggi. The try-out data were used to analyze the validity, reliability, discriminating power, and difficulty index of the items. The analysis showed that the items were suitable for use by students. The reliability of the instrument was calculated using the *Cronbach's Alpha* formula (Arikunto, 2018) and a coefficient of 0.7022 was obtained, which falls into the high category. This shows that the final test try-out items have good consistency in measuring mathematical problem-solving ability. Quiz data were analyzed descriptively based on students' mean scores on each indicator of mathematical problem-solving ability. The final test data were analyzed in three stages, namely the normality test using the *Anderson-Darling* test, the homogeneity test using the *F-test*, and the hypothesis test using the t-test at a significance level of $\alpha = 0.05$ to determine whether the mathematical problem-solving ability of students who learned with the *Problem Based Learning* (*PBL*) model is better than that of students who received direct instruction.

## 3. RESULT AND DISCUSSION

### 3.1 Quizzes

The development of students' mathematical problem-solving ability during the implementation of the *Problem Based Learning* (PBL) model was examined based on the mean quiz scores on each indicator obtained over six meetings. The quizzes were given to determine students' achievement in identifying the known and asked elements, formulating the problem or constructing a mathematical model, applying formulas or mathematical models to solve problems, and explaining and interpreting the solution results. Through these quiz results, changes in achievement on each indicator can be observed from one meeting to the next. Thus, the development of students' mathematical problem-solving ability during PBL learning can be identified from the increase in mean scores on each indicator. The development of the experimental class students' mean quiz scores over six meetings is presented in Figure 1.

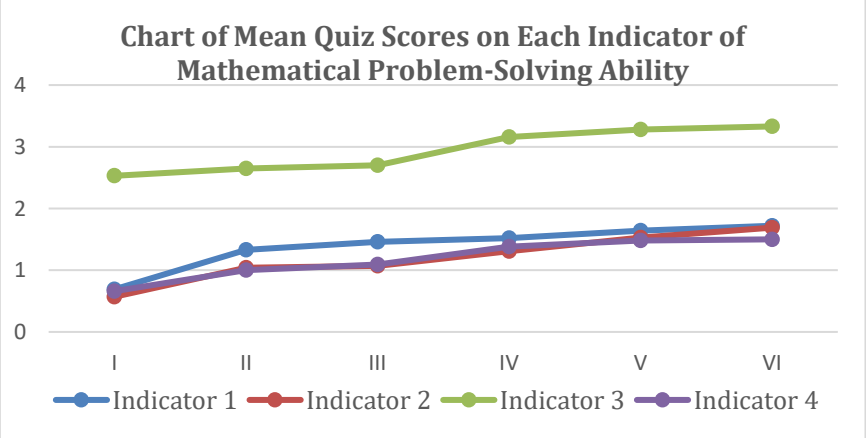



**Figure 1.** Development of Mean Quiz Scores for Each Indicator of Mathematical Problem-Solving Ability

Based on Figure 1, students' mean quiz scores on the four indicators of mathematical problem-solving ability tended to increase from the first to the sixth meeting. Indicators 1, 2, and 4 showed score increases with a maximum score of 2, while indicator 3 also increased with a maximum score of 4, although its development was not as optimal as the other indicators. Overall, these quiz results describe the development of students' mathematical problem-solving ability during the implementation of the *Problem Based Learning* model.

### 3.2 Final Test

After the material on polyhedra (flat-sided solids) had been studied, students in the experimental and control classes were given a final test to obtain data on mathematical problem-solving ability. The test results were used to determine students' achievement in mathematical problem-solving ability after learning in each class. The data were analyzed through normality and homogeneity tests as prerequisites for hypothesis testing at a significance level of $\alpha = 0.05$. The test results are presented in Table 2.

**Table 2.** Results of Normality and Homogeneity Tests of Final Test Data

| Type of Test | Class | $P-value$ | $\alpha$ | Decision | Conclusion |
|---|---|---|---|---|---|
| Normality *(Anderson-Darling)* | Experimental | 0.210 | 0,05 | $H_0$ accepted | Normally Distributed |
| | Control | 0.373 | 0,05 | $H_0$ accepted | Normally Distributed |
| Homogeneity *(F-test)* | Experimental and Control | 0.809 | 0,05 | $H_0$ accepted | Homogeneous Variance |

The normality test results show that both sample classes meet the normality assumption because they obtained a *P-value* > α. Furthermore, the homogeneity test results show that both sample classes have homogeneous variances because the *P-value* > α. Based on the t-test results, the *P-value* was $0.013 < \alpha$, so $H_0$ is rejected. Thus, the mathematical problem-solving ability of students who learned using the *Problem Based Learning* (PBL) model is better than that of students who learned using the direct instruction model. The results of the mathematical problem-solving test in both sample classes are presented in Table 3.

**Table 3.** Final Test Results of Students' Problem-Solving Ability by Class

| Class | N | Mean score | StDev | Highest Score | Lowest Score |
|---|---|---|---|---|---|
| Experimental | 30 | 20.16 | 6.44 | 28.90 | 6.30 |
| Control | 30 | 16.27 | 6.74 | 28.60 | 1.30 |

The experimental class obtained a mean final test score of 20.16, while the control class obtained 16.27. Based on Table 3, students who learned using the *Problem Based Learning* model showed better mathematical problem-solving ability than students who learned using the direct instruction model. The highest score achieved by the experimental class was 28.90, while the control class reached 28.60. However, the lowest score in the experimental class, 6.30, was still far above that of the control class, which reached only 1.30. This shows that students with the lowest achievement in the experimental class still obtained better scores than students in the control class. The standard deviation was 6.44 for the experimental class and 6.74 for the control class, which indicates that the spread of scores in the two classes did not differ much. Achievement on each indicator of mathematical problem-solving ability is detailed in Table 4.

**Table 4.** Achievement on Each Indicator of Mathematical Problem-Solving Ability

| Indicator | Maximum Score | Experimental Class | Control Class |
|---|---|---|---|
| Identifying the known elements, the asked elements, and the adequacy of the required elements | 6 | 4.74 | 3.90 |
| Formulating the mathematical problem or constructing a mathematical model | 6 | 3.96 | 2.63 |
| Applying formulas or mathematical models to solve problems | 12 | 8.10 | 7.61 |
| Explaining or interpreting the solution results | 6 | 3.36 | 2.13 |

Table 4 presents the achievement of the experimental and control classes on each indicator of mathematical problem-solving ability. Based on the table, the experimental class obtained higher mean scores than the control class on all four indicators. On indicator 1, the experimental class obtained a mean score of 4.74, while the control class obtained 3.90 out of a maximum score of 6. This difference shows that experimental class students were better able to identify known information, determine what was asked, and recognize the adequacy of information in the problem. This achievement is in line with the characteristics of the *Problem Based Learning* (PBL) model, which makes a problem the starting point of learning, so that students are encouraged to understand the problem and seek the information needed to solve it (Maryati, 2018). This difference can occur because students in the experimental class were confronted with problems that needed to be understood and analyzed before conducting an investigation. Through this process, students practiced examining the available information, determining what needed to be found, and assessing the adequacy of information for solving the problem. In the control class, students mostly followed the teacher's explanations and examples, so opportunities to analyze the important elements of the problem themselves were more limited.

On indicator 2, the experimental class's mean score was 3.96, while the control class's was 2.63 out of a maximum score of 6. This shows that experimental class students were better able to formulate problems and construct mathematical models. The stage of guiding individual and group investigation in PBL encourages students to collect information, analyze problems, and determine an appropriate mathematical model as the basis for a solution (Siswanto & Meiliasari,

2024). This can occur because students need to process the information they have identified and connect it with relevant mathematical concepts to construct a mathematical model. Through group discussion, students can also exchange opinions in determining the relationships among elements in the problem. Experimental class students had the opportunity to investigate problems and develop models through discussion, while control class students mostly followed the teacher's solution examples.

On indicator 3, the experimental class's mean score was 8.10 and the control class's was 7.61 out of a maximum score of 12. This difference is the smallest among the four indicators, but it still shows that the experimental class was better at applying formulas or mathematical models to solve problems. At the investigation stage, students tried solution strategies, discussed the appropriate steps, checked the accuracy of those steps, and corrected the errors they found. The experimental class's advantage can occur because the investigation and discussion activities in PBL give students the opportunity to determine solution strategies and apply formulas appropriate to the problem they face. This finding is in line with Marsal & Mirna (2026) who stated that group discussion and guidance in PBL open space for students to exchange ideas in determining the right formula. In the control class, the application of formulas tended to follow procedures already exemplified by the teacher.

On indicator 4, the experimental class obtained a mean score of 3.36, while the control class obtained 2.13 out of a maximum score of 6. This shows that experimental class students were better at explaining and interpreting the solution results. This achievement is related to the stages of developing and presenting work and of analyzing and evaluating the problem-solving process. At these stages, students presented their answers, assessed their suitability to the problem, and drew conclusions appropriate to the context. This is because experimental class students had the opportunity to explain the solution results and convey the reasons for the strategies used through presentations and discussion. These activities encouraged students to recheck their answers and relate them to the question being asked, so that they did not focus only on the calculation results. This is in line with Santoso et al. (2018) who noted that problem solving in PBL includes rechecking answers and drawing conclusions. In the control class, students tended to focus on obtaining answers based on procedures exemplified by the teacher.

Overall, Table 4 shows that the experimental class obtained higher mean scores than the control class on all four indicators. This shows that students who learned using the *Problem Based Learning* model were better able to identify the known elements, the asked elements, and the adequacy of the required elements, formulate the problem or construct a mathematical model, apply formulas or mathematical models to solve problems, and explain or interpret the solution results. This advantage is related to learning stages that involve students actively in the problem-solving process, from understanding the problem, investigating and discussing, to presenting and evaluating the solution results. In the control class, learning activities were centered mostly on the teacher's explanations and examples, so students had more limited opportunities to go through this process. This finding is in line with Luthfiah et al. (2023) who reported that problem-based learning produces better mathematical problem-solving ability than direct instruction. Thus, applying PBL can be an alternative in mathematics learning to give students the opportunity to develop problem-solving ability through active involvement in every stage of problem solving.

## 4. CONCLUSION

Based on the research results, the mathematical problem-solving ability of students who learned using the *Problem Based Learning* (PBL) model increased gradually over six meetings. This increase was seen in all four indicators of mathematical problem-solving ability, namely identifying the known and asked elements, formulating the problem or constructing a mathematical model, applying formulas or mathematical models to solve problems, and explaining and interpreting the solution results. In addition, the final test results show that the mathematical problem-solving ability of students who learned using the PBL model was better than that of students who learned using the direct instruction model. These results show that the PBL model is more effective in improving the mathematical problem-solving ability of Grade IX students at SMP Negeri 2 Bukittinggi than the direct instruction model. Therefore, the PBL model can be used as an alternative in mathematics learning because it gives students the opportunity to understand problems, conduct investigations and discussions to find solutions, and present and evaluate problem-solution results. This study has limitations in that the Problem Based Learning (PBL) model was applied only to the topic of polyhedra (flat-sided solids) and to Grade IX students at SMP Negeri 2 Bukittinggi. Therefore, future research could examine the application of the PBL model to different learning topics and educational levels to obtain a broader picture of the model's effectiveness in improving mathematical problem-solving ability.

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