



THE EFFECT OF PROBLEM-BASED LEARNING ON MATHEMATICS LEARNING OUTCOMES CONTROLLING FOR STUDENTS' NUMERICAL ABILITY

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Abstract. Difficulties in understanding mathematical concepts remain a major problem among elementary school students, particularly when learning is dominated by conventional teaching methods that limit critical thinking and problem-solving skills. This study aims to examine the effectiveness of the Problem-Based Learning (PBL) model in improving fifth-grade students' mathematics achievement while controlling for numerical ability as a covariate. A quasi-experimental design with a single-factor independent groups design using covariates was employed. The participants consisted of 74 fifth-grade students from Gugus 5 Bima, comprising 37 students from SDN 1 Baluk as the experimental group taught using PBL and 37 students from SDN 2 Banyubiru as the control group taught using conventional methods. Data were collected using validated and reliable tests of numerical ability and mathematics achievement, and analyzed using ANCOVA after meeting the assumptions of normality, homogeneity, and linearity. The results indicate that students taught using the PBL model achieved significantly higher mathematics scores than those taught using conventional methods ($F = 47.334$, $p < 0.05$). Furthermore, after controlling for numerical ability, the PBL model remained significantly more effective in improving students' mathematics achievement compared to conventional instruction ($F = 14.135$, $p < 0.05$). In conclusion, the PBL model is effective in enhancing elementary students' mathematics achievement and can be recommended as an instructional approach to support deeper conceptual understanding and problem-solving skills.

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INTRODUCTION

Despite mathematics being a fundamental subject in elementary education, students' mathematics learning outcomes remain relatively low, particularly in terms of conceptual understanding and problem-solving skills. Various national and international assessments reveal that many elementary school students experience difficulties in understanding basic mathematical concepts and applying them in real-life contexts. This condition indicates a gap between the expected learning outcomes of mathematics education and the actual learning achievements attained by students in classroom practices.

Mathematics is one of the fundamental and essential subjects in the elementary education curriculum, playing a crucial role in developing students' logical, analytical, critical, creative, and systematic thinking skills (Fahrrozi & Sukrul Hamdi, 2017; Nareswari et al., 2021; Narpila & Sihotang, 2022). Mastery of mathematics from the early stages of education functions not only as academic preparation but also as the foundation for 21st-century skills required in everyday life (Rahayu et al., 2022; Yudha et al., 2021). However, in practice, mathematics learning is often perceived by students as difficult and monotonous (Ida Zulaeliyah, 2021; Susanti et al., 2022).

This condition is reflected in various national data. According to the 2023 National Assessment (AN) report, many elementary school students experience difficulties in understanding basic mathematical concepts and applying them in contextual situations (Badan Standar, 2022). This finding is consistent with UNESCO's (2021) report, which indicates that fewer than one-third of Indonesian students are able to solve mathematics problems at the basic

level of the Programme for International Student Assessment (PISA) (OECD, 2022). These findings suggest that mathematics learning has not yet fully addressed the needs and characteristics of today's students (Astuti et al., 2023; Dewi & Lestari, 2020; Mubasiroh et al., 2019).

One of the major factors contributing to low mathematics learning outcomes is the continued use of conventional, teacher-centered instructional approaches that emphasize lectures and routine exercises (Gusteti & Neviyarni, 2022; Mulyati & Evend, 2020). Such approaches do not provide sufficient opportunities for students to explore, discuss, and construct their own understanding (Dewi et al., 2023). As a result, students' participation and motivation tend to be low, highlighting the need for innovative learning models that position students as active learners and provide meaningful, contextual learning experiences (Lestari et al., 2021; Padji et al., 2024).

One relevant learning model is Problem-Based Learning (PBL). PBL emphasizes students' active involvement in solving real-world problems that are relevant to their lives to acquire new knowledge (Merici, 2023; Rihayati et al., 2023). This model has been proven to enhance conceptual understanding, critical thinking, collaboration, and problem-solving skills (Silver, 2004). The findings of Elya & Ratnaningsih (2025) also indicate that the Problem-Based Learning model has a positive effect on mathematics learning outcomes in elementary schools.

In addition to learning models, students' numerical ability also plays a crucial role in the success of mathematics learning (Lestari, 2019; Nareswari et al., 2021). Numerical ability encompasses basic skills such as calculation, pattern recognition, and understanding numerical relationships (Aini et al., 2024; Sitriani et al., 2020). Students with high numerical ability tend to understand mathematical concepts more easily, whereas those with low numerical ability often struggle to follow the lessons (Andhany & Maysarah, 2023; Lestari, 2019). Unfortunately, many previous studies did not control for the numerical ability variable, resulting in findings that have not provided a comprehensive picture of the effectiveness of PBL.

Several recent studies have highlighted the relationship between numerical ability and mathematics learning achievement. Nuranti & Hasratuddi (2023) found that numerical ability contributes significantly to students' mathematics performance, while Aini et al. (2024) reported that students' numerical ability influences their mathematical investigation skills. Similarly, Silalahi & Hendriawan (2022) demonstrated that numerical ability plays an important role in elementary students' ability to solve mathematics problems requiring Higher Order Thinking Skills (HOTS). In addition to cognitive factors, instructional approaches have also been shown to affect mathematics learning outcomes. Ningrum et al. (2023) and Tohang et al. (2023) reported that the Problem-Based Learning (PBL) model is more effective in improving students' problem-solving skills and conceptual understanding in mathematics learning.

Despite the extensive body of research on Problem-Based Learning and numerical ability, most previous studies have examined these variables independently. Limited research has investigated the effectiveness of PBL while statistically controlling for students' numerical ability. Consequently, the true instructional impact of PBL on mathematics learning outcomes may not have been fully revealed. Therefore, this study aims to examine the effect of Problem-Based Learning on elementary students' mathematics learning outcomes by controlling for numerical ability as a covariate using ANCOVA analysis. By addressing this research gap, the study is expected to provide a more accurate understanding of the effectiveness of PBL and to contribute empirical evidence for mathematics learning practices that account for students' initial numerical abilities.

RESEARCH METHODS

The research design employed in this study was a quasi-experimental design in the form of a single-factor independent groups design with the use of a covariate. According to Dantes (2017), the variables used in this design are continuous, such as intelligence, and are referred to as concomitant variables or covariates (Sugiyono, 2022). In this study, two learning models were compared: the Problem-Based Learning (PBL) model and the conventional learning model. The study involved one independent variable, one dependent variable, and one covariate; therefore,



the data were analyzed using Analysis of Covariance (ANCOVA).

The purpose of this research was to examine the effect of the two learning models on students' mathematics learning outcomes. Since students' mathematics achievement is also influenced by their numerical ability, this variable was controlled as a covariate in the analysis. An illustration of the single-factor independent groups design with the use of a covariate is presented in Table 1.

Table 1. Single Factor Independent Groups Design With Use of Covariate

A1		A2	
X	Y	X	Y
Description: A1: Problem-Based Learning Model; A2: Conventional Learning Model; Y: Mathematics Learning Outcomes; X: Numerical Ability			

The research subjects were fourth-grade students in Cluster 5 Bima, which consisted of nine elementary schools: SDN 1 Baluk, SDN 2 Baluk, SDN 3 Baluk, SDN 4 Baluk, SDN 5 Baluk, SDN 1 Banyubiru, SDN 2 Banyubiru, SDN 3 Banyubiru, and SDN 4 Banyubiru. Among these schools, SDN 1 Baluk was designated as the experimental group, comprising 37 students who received instruction using the PBL model, while SDN 2 Banyubiru was designated as the control group, comprising 37 students who received conventional instruction. The selection of schools was carried out through purposive sampling based on the equivalence of student characteristics and recommendations from the schools (Setyosari, 2015).

In this study, two hypotheses were formulated for testing. The first hypothesis examines whether applying the Problem-Based Learning (PBL) model affects the mathematics learning outcomes of fifth-grade students, independent of their numerical ability. The second hypothesis examines whether the effect of the PBL model on mathematics learning outcomes remains significant after controlling for students' numerical ability as a covariate. Thus, the purpose of this study is to determine the effectiveness of PBL both directly and independently of students' numerical ability.

The research procedure began with administering a numerical ability test as a pretest (covariate), followed by the learning treatments according to group assignment (PBL for the experimental group and conventional methods for the control group), and concluded with a mathematics achievement test as the posttest. The research instruments consisted of a numerical ability test and a mathematics achievement test, both of which were validated by mathematics education experts and found to be reliable (Cronbach's Alpha > 0.7), thus meeting the feasibility requirements. The data were analyzed using SPSS version 25, following these steps: prerequisite tests (normality using the Kolmogorov-Smirnov/Shapiro-Wilk test and homogeneity of variance using Levene's Test), followed by a one-way ANCOVA to determine the effect of the PBL model on mathematics learning outcomes with numerical ability as a covariate. With this design, the study can be replicated by other researchers in similar contexts.

RESULTS AND DISCUSSION

The data obtained in this study were described according to each treatment group. The data were classified into four categories: (1) students' numerical ability in the Problem-Based Learning (PBL) group, (2) students' numerical ability in the conventional learning group, (3) students' mathematics learning outcomes in the PBL group, and (4) students' mathematics learning outcomes in the conventional learning group. Through this classification, the study was able to compare the effect of the PBL model on mathematics learning outcomes, both directly and after controlling for numerical ability as a covariate.

Before testing the hypotheses, prerequisite analyses were conducted, consisting of normality testing, homogeneity of variance testing, and linearity testing. These tests are essential to ensure that the data meet the basic assumptions of parametric statistical analysis. Once these assumptions are met, the Analysis of Covariance (ANCOVA) can be validly applied, and the interpretation of the results can be scientifically justified.

Normality Test

The purpose of the normality test is to determine whether the mathematics learning outcome



data in the experimental and control classes are normally distributed. A normal data distribution is a prerequisite for the use of parametric analysis, ensuring that the test results more accurately represent the condition of the population. In this study, the normality test was conducted using the Kolmogorov-Smirnov test. The results of the normality test are presented in [Table 2](#).

Table 2. Summary of Normality Test Results

Group	Kolmogorov-Smirnov (Sig.)	Remarks
X1	0.2	Normal
X2	0.2	Normal
Y1	0.154	Normal
Y2	0.065	Normal

Homogeneity Test

Subsequently, a homogeneity-of-variance test was conducted to examine whether the variances of mathematics learning outcomes between the experimental and control groups were equal. The homogeneity test in this study was carried out using Levene's Statistic. The results showed a p-value greater than 0.05, indicating that the variances between groups were homogeneous. The detailed results of the homogeneity test are presented in [Table 3](#).

Table 3. Summary of Homogeneity Test Results

	F	df1	df2	Sig.
Numerical Ability	0.003	1	72	0.957
Learning Outcomes	1.84	1	72	0.179

Regression Linearity Test

The regression linearity test was conducted to determine the relationship between numerical ability and mathematics learning outcomes in both the experimental and control groups. This test aimed to ensure that the relationship between the independent and dependent variables was linear, meaning that increases in numerical ability were associated with increases in learning outcomes, and vice versa. The results showed a p-value greater than 0.05, indicating that the relationship between the independent and dependent variables was linear. The results of the regression linearity test are presented in the following table. The complete results are shown in [Table 4](#).

Table 4. Summary of Regression Linearity Test Results

	F	Significance (Sig.)	Conclusion
Significance of Regression Direction	73.16	0	Significant
Linearity	0.649	0.792	Linear

Hypothesis Testing

The first hypothesis states that the application of the Problem-Based Learning (PBL) model has an effect on the mathematics learning outcomes of fifth-grade students. The analysis results related to this hypothesis are presented in [Table 5](#).

Table 5. Results of the First Hypothesis Testing

Source of Variance	JK	db	RJK	F	Sig.
Learning Model (Between A)	437,838	1	437,838	47,334	0,000
Within	666	72	9,250	-	-
Total	28970	74	-	-	-

To determine whether the null hypothesis in the first hypothesis is accepted or rejected, attention is given to the F-value. Based on the table, the obtained F-value was 47.334 with a significance level of < 0.05 . With $\alpha = 0.05$, it is evident that the significance value (Sig. = 0.000) is smaller than α . Therefore, H_0 is rejected and H_1 is accepted. Thus, it can be concluded that the Problem-Based Learning (PBL) model has a significant effect on the mathematics learning outcomes of fifth-grade students.

The second hypothesis states that after students' numerical ability is controlled, the



mathematics learning outcomes of students who follow the Problem-Based Learning (PBL) model are higher than those of students who follow the conventional learning model. The analysis results related to this hypothesis are presented in [Table 6](#).

Table 6. Results of the Second Hypothesis Testing

Source of Variation	JK	df	RJK	F	Sig.
Learning Model after Controlling Numerical Ability (Between A)	88,143	1	88,143	14,135	0,000
Within	442,728	71	6,236	-	-
Total	28970	74	-	-	-

To determine whether the null hypothesis of the second hypothesis is accepted or rejected, attention is given to the calculated F value and its significance level. Based on the table, the calculated F value is 14.135 with a significance level < 0.05 . By setting $\alpha = 0.05$, it can be seen that the significance value (sig. = 0.000) is smaller than α . Therefore, H_0 is rejected and H_1 is accepted. Thus, after controlling for students' numerical ability, the mathematics learning outcomes of students taught using the Problem-Based Learning (PBL) model are significantly higher than those of students taught using the conventional learning model.

Based on the test results, the first hypothesis indicates that the Problem-Based Learning (PBL) model has an effect on the mathematics learning outcomes of fifth-grade students. The calculated F value was 47.334 with a significance level of < 0.05 ; therefore, H_0 was rejected and H_1 was accepted. This shows that students who participated in learning using the PBL model achieved better learning outcomes compared to those who learned through conventional methods ([Andhany & Maysarah, 2023](#); [Tohang et al., 2023](#)). Student learning outcomes are influenced by individual abilities, group interactions, and the conditions of the learning process ([Zaini & Sutirna, 2021](#)).

This finding is consistent with the study of [Susino et al. \(2023\)](#), which demonstrated that the implementation of PBL improves problem-solving skills and mathematics learning outcomes in elementary students. Similarly, [Padji et al. \(2024\)](#) found that students who learned through PBL achieved higher learning outcomes and were able to apply mathematical concepts in contextual situations. These results are also in line with [Boangmanalu et al. \(2023\)](#), who stated that PBL is effective in improving numeracy skills and mathematical problem-solving abilities. Furthermore, this finding reinforces [Silver \(2004\)](#) assertion that PBL positions students as active subjects who are required to explore, analyze, and synthesize information in solving real-world problems.

The second hypothesis tested whether the effect of PBL remained significant after controlling for students' numerical ability. The analysis results showed an F value of 14.135 with sig. < 0.05 , thus H_0 was rejected and H_1 was accepted. Accordingly, after controlling for numerical ability, students who learned with the PBL model still achieved significantly higher mathematics learning outcomes compared to those who participated in conventional learning ([Ate & Lede, 2022](#)). Learning outcomes are influenced by internal factors such as students' abilities and talents, as well as external factors such as the strategies or learning models employed. Controlling for numerical ability in this study indicates that the improvement in learning outcomes through the PBL model is not solely influenced by students' initial abilities but also by the effectiveness of the learning model itself. This finding is consistent with [Hakiki & Lubis \(2025\)](#), who reported that PBL is more effective in enhancing mathematics learning outcomes even when students' initial numerical abilities vary, as well as highlighting the interaction between learning models and numerical ability on learning achievement.

The PBL model not only helps students understand concepts and improve learning outcomes but also enhances interaction skills, interest, and learning motivation, as it incorporates elements of collaboration, group discussion, and recognition for both individuals and groups ([Gusteti & Neviyarni, 2022](#); [Mewalo et al., 2025](#)). In addition, this model can indirectly improve students' numerical ability, since each member is responsible for understanding the topic and teaching it to peers. Consequently, numerical ability and mathematical problem-solving skills develop simultaneously. Students with stronger numerical abilities tend to have higher self-



confidence in solving mathematical problems, which ultimately supports the overall improvement of learning outcomes.

These findings are consistent with recent studies within the last five years, which emphasize the effectiveness of PBL (Gunur et al., 2020; Halizah & Napfiah, 2024; Rezky et al., 2022; Silalahi & Hendriawan, 2022). Overall, the results of this study confirm that the implementation of the Problem-Based Learning (PBL) model is effective in improving elementary school students' mathematics learning outcomes, both directly and after controlling for numerical ability. This model can align the learning process with students' characteristics and individual abilities, thereby providing a meaningful, interactive, and contextual learning experience.

CONCLUSIONS AND SUGGESTIONS

This study demonstrates that the Problem-Based Learning (PBL) model significantly improves fifth-grade students' mathematics learning outcomes compared to conventional instruction. After controlling for students' numerical ability, the effectiveness of PBL remains higher, confirming that improvements in learning outcomes are influenced not only by students' prior abilities but also by the learning model itself. In addition to enhancing learning outcomes, PBL fosters the development of numerical ability, collaboration skills, and students' self-confidence in solving mathematical problems. These findings provide a foundation for teachers to design mathematics instruction that is more contextual, interactive, and adaptive, while also opening avenues for further research on the integration of technological media and motivational and creativity-related factors.

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