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The Influence of PBL Learning Model on High School Students' Learning Outcomes in System of Linear Equations in Three Variables Material

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ABSTRACT

This study aims to determine how the application of the problem-based learning model affects the learning outcomes of class X students regarding the material on systems of linear inequalities in three variables. This research is a pre-experimental one-group pretest-posttest design, with class X research subjects at Al-Hidayah Islamic High School. The instrument used is a validated system of linear inequalities in a three-variable material understanding test. The analyses used in this study are descriptive and inferential. The study found a big improvement in learning results after using the problem-based learning (PBL) method for the System of Linear Inequalities in Three Variables material, with an average score of 46.0833 before the test and 75.6667 after. The significant value of the hypothesis test is below 0.05, which means 0.00 < 0.05; thus, H0 is rejected and H1 is accepted. This study shows a significant difference in student learning outcomes when using the Problem-Based Learning (PBL) learning model.

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1. INTRODUCTION

Early instruction in mathematics is crucial for students. Mathematics is crucial for daily activities, including counting (Greer & Erickson, 2019). Research by Ati and Setiawan (2020) shows that mathematics is an important discipline in elementary education because it encourages the development of logical, systematic, critical, and creative thinking in children. Mathematics is a discipline that students learn through problem-solving. The goal of this learning is to improve students' cognitive abilities in resolving abstract and practical difficulties encountered in everyday life (Căprioară, 2015). Students must acquire or use their mathematical problem-solving skills to solve mathematical problems (Christina & Adirakasiwi, 2021). One of the goals of the Minister of Culture, Research, and Technology Regulation Number 008/H/KR/2022 concerning Mathematics Education is for students to acquire problem-solving skills,

which include the ability to understand problems, formulate mathematical models, solve these models, and interpret the resulting answers. This method consists of five elements: mathematical reasoning and proof, mathematical problem solving, communication, mathematical representation, and mathematical relationships. The Independent Curriculum defines mathematical problem-solving as the process of solving mathematical or real-world problems through the application and adaptation of various successful strategies (Juniati & Jamaan, 2024).

Because mathematics is highly abstract and demands logical and systematic thinking, many students find it difficult at the senior high school level (van Velzen, 2016). The System of Linear Equations in Three Variables is a challenging mathematics subject in 10th grade, requiring a deep understanding of concepts and the ability to apply appropriate solution methods. Many students struggle to grasp the material because the learning methods for the system of linear equations in three variables are still conventional and do not actively involve them. To address this issue, learning must be transformed with new methods that encourage active student participation and enhance higher-order thinking skills. Problem-Based Learning (PBL) is a learning model considered effective because it is student-centered and uses real-world problems as stimuli (Muzaini et al., 2022; Anggraeni et al., 2023). Problem-based learning is the ability students possess to solve problems that arise in everyday life. Because each student has a different level of understanding of how to solve problems, their problem-solving abilities naturally vary. Problem-solving serves as a link between learning and performance. This means transforming knowledge into behavior and leading to goal achievement, according to Mangaroska et al. (2022).

PBL encourages critical thinking, teamwork, and collaborative problem-solving among students. Usman et al. (2022) emphasized that the System of Linear Equations in Three Variables is a mathematics learning resource closely related to students' everyday experiences. System of Linear Equations in Three Variables is a secondary education learning resource related to everyday problems. Human resource development depends on mathematics education. The system of linear equations in three variables uses three variables: x, y, and z. This topic often presents challenges for 10th-grade students in understanding and solving mathematical problems. We need more innovative and engaging pedagogical approaches to address this issue. Improving student learning outcomes is crucial.

The problem-based learning model highlights that students learn best when their activities involve real and meaningful math tasks or problems in the independent curriculum, especially in problem-solving (Rézio et al., 2022; Anugraheni et al., 2025). The Head of the BSKAP Ministry of Education articulates this in its context. The fundamental goal of education is to address real-world challenges. Therefore, the knowledge and theories provided must not simply be memorized and understood; they must be connected to reality and utilized to address existing problems.

Problem-based learning is an educational model that uses problems as a catalyst for gaining new insights. Findings indicate that problem-based learning is a process (Boye & Agyei, 2023). Learning begins with a real-world challenge, encouraging students to

analyze the problem through the lens of their existing knowledge, thus facilitating the emergence of new insights from their prior understanding (Dahl, 2018).

Additionally, Problem-Based Learning is an educational model that emphasizes real-world challenges to develop students' critical and creative thinking skills (Wardani & Fiorintina, 2023; Anggraeni et al., 2023). Consequently, this paradigm equips students to improve problem-solving in real-world scenarios. Previous research has shown that Problem-Based Learning improves students' mathematical understanding (Hendriana et al., 2018). The problem-based learning model is used to equip students with knowledge and problem-solving skills by addressing real-life problems through the stages of the scientific method. This explanation shows that PBL engages students in contextual problem-solving. The problem-based learning (PBL) model prioritizes problem-solving tasks and encourages the development of students' critical thinking skills. The PBL methodology allows students to improve their critical thinking skills through problem-solving tasks.

It is hoped that PBL can help students learn. This model presents students with real-life situations or problems, thereby increasing their engagement in comprehending the System of Linear Inequalities in Three Variables material. Previous research has shown that PBL can improve students' conceptual understanding, problem-solving skills, and desire to learn (Aydin, 2014; Shishigu et al., 2017). Furthermore, another study conducted results of the regression test used in this study showed a strong relationship between PBL and students' mathematics learning outcomes (Dalila et al., 2022).

Therefore, the purpose of this study is to empirically analyze the effect of the PBL learning method on tenth-grade students' learning outcomes in System of Linear Inequalities in Three Variables material. We want to determine whether the use of PBL can improve students' ability to understand and solve mathematics problems related to System of Linear Inequalities in Three Variables. We hope this study will uncover empirical evidence that validates the use of PBL as an alternative learning method.

2. METHOD

This research employed quantitative methods. This research is pre-experimental and involved one group, called the experimental group, without a comparison or control group. This research was conducted at Al-Hidayah Islamic High School, involving 10th-grade students in the even semester of the 2024-2025 academic year. The dependent variable (Y) was students' mathematical learning outcomes on the topic "System of Linear Inequalities in Three Variables." The independent variable (X) was the Problem-Based Learning (PBL) model. Figure 1 presents this study's one-group pretest-posttest design.

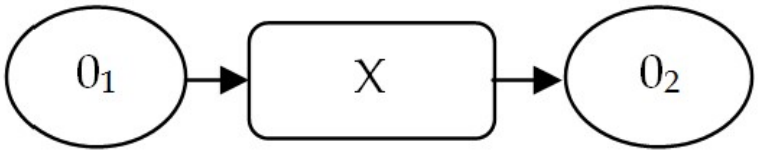

Figure 1. One-Group Pretest-Posttest Design

This study used a three-item essay question as a measurement tool. The testing instrument has been empirically validated. This assessment was conducted to evaluate the learning outcomes of 10th-grade students related to the System of Linear Inequalities in Three Variables material. The assessment was conducted twice: a pre-test before implementing problem-based learning (PBL) techniques and a post-test after their implementation. The analysis used in this study is descriptive and inferential analysis.

3. RESULTS AND DISCUSSION

Results

This section describes the results of data processing and examines the research findings. This study analyzes the learning outcomes of 10th-grade students assessed on the System of Linear Inequalities in Three Variables material using a problem-based learning approach. The data analysis presents the results using both descriptive and inferential methods.

Descriptive Statistical Analysis Results

This descriptive analysis uses a problem-based learning strategy to describe the distribution of mathematics learning outcomes scores for 10th graders at Al-Hidayah Islamic High School. This study presents the mean, standard deviation, maximum and minimum scores, and the completeness of student learning outcomes.

Table 1. Frequency Distribution of Students' Mathematics Learning Outcomes

No.	Name	Pre-test Score	Post-test Score
1	C H A	20	78
2	F I A	43	83
3	O C P	43	78
4	R S	54	72
5	S F K	78	80
6	M S W	78	98
7	S N A B	54	71
8	V M S	30	59
9	M R D H	34	60
10	R D H	25	63
11	P A	40	83
12	M J V W A	54	83

Table 1 shows that the learning outcomes of students using the PBL learning model have met the established minimum competency. However, there are still some students who have not achieved the required minimum competency criteria score.

Next, descriptive analysis is used to explain or characterize data collected in research. The goal is to convey facts methodically and accurately without extrapolating them to a wider audience. Descriptive analysis allows researchers to understand patterns,

distributions, and trends in data, thereby increasing its significance and facilitating understanding. This research generally includes data presentation through frequency distribution tables, mean, median, mode, standard deviation, maximum and minimum values, and data visualization through graphs or diagrams. Table 2 below presents the findings of the data analysis.

Table 2. Student Response Results to the Problem Based Learning Model

			Statistic	**Std. Error**
PRE	Mean		46.0833	5.37314
	95% Confidence Interval for Mean	Lower Bound	34.2571	
		Upper Bound	57.9095	
	5% Trimmed Mean		45.7593	
	Median		43.0000	
	Variance		346.447	
	Std. Deviation		18.61309	
	Minimum		20.00	
	Maximum		78.00	
	Range		58.00	
	Interquartile Range		23.00	
	Skewness		.561	.637
	Kurtosis		-.308	1.232
POS	Mean		75.6667	3.26676
	95% Confidence Interval for Mean	Lower Bound	68.4766	
		Upper Bound	82.8568	
	5% Trimmed Mean		75.3519	
	Median		78.0000	
	Variance		128.061	
	Std. Deviation		11.31639	
	Minimum		59.00	
	Maximum		98.00	
	Range		39.00	
	Interquartile Range		18.00	
	Skewness		.133	.637
	Kurtosis		.018	1.232

The data in Table 2 shows that students who participated in problem-based learning had an average response of 75.66, with a mode of 83 (the most common value) and a median of 78.00 (the middle value). This indicates that half of the students in the sample scored 78.00 or lower, while the mean value was in the middle of the sample. The variance was 128.061, and the standard deviation was 11.31639. With a minimum value of 59.00 and a maximum of 98, the range of data for the wisdom values obtained from the 12 students who used the problem-based learning model was 39.00.

Inferential Statistical Analysis Results

The research hypothesis is derived from the results of inferential statistical analysis, which is an extension of descriptive analysis. The normality test is the first step in this analysis; it checks whether the data comes from a normally distributed population. Hypothesis testing using ANOVA and paired-sample t-tests is performed after the

normality test is completed. The collected data was checked for normal distribution using a normality test. To assess the research hypothesis and draw conclusions, a normality test must be performed. At a significance level of $\alpha = 0.05$, the following criteria apply to ensure data normality: If the obtained p.sig. is greater than α, then the sample is representative of a normally distributed population (H1); otherwise, the sample is not indicative of a normally distributed population (H0). The data distribution was checked for normality using a normality test. In their study, the researchers used SPSS and the Kolmogorov-Smirnov test. The problem-based learning method's student response assessment yielded a sig = 0.362 > 0.05 result, while the System of Linear Inequalities in Three Variables content yielded a sig = 0.463 > 0.05 score. The results show that all data are regularly distributed because all data are significantly greater than the 0.05 significance level. The normality test has been met.

When comparing means across multiple data sets, the ANOVA test is a powerful statistical tool for identifying statistically significant differences. Consequently, investigations with multiple treatment groups or categories yield quite effective results. Decision-making approach: If the significance level is less than 0.05, the means are different, according to the One-Way ANOVA test. Conversely, if the significance level is greater than 0.05, the means are the same. Herbal remedies A, B, and C have significantly varying effects on treating various diseases, as shown by the results above, with a significance value of 0.015 being less than 0.05. See below for the results of the ANOVA test calculations.

Table 3. ANOVA Analysis Results

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1145.500	7	163.643	2.487	.198
Within Groups	263.167	4	65.792		
Total	1408.667	11			

Based on Table 3, the posttest significance value for student learning outcomes was 0.198, which is greater than 0.05 (0.198 > 0.05). This means that in the final condition (after treatment), the sample had balanced abilities. Additionally, the paired samples t-test is effective for testing differences between two conditions in the same sample with normally distributed quantitative data. This is especially true for studies involving pre- and post-treatment measurements. The following shows the results of the paired samples t-test calculation.

Table 4. Paired Samples Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE	46.0833	12	18.61309	5.37314
	POS	75.6667	12	11.31639	3.26676

The average pretest score for student learning outcomes was 46.0833, according to data obtained from SPSS Paired Samples Statistics. The average posttest score for student learning outcomes for System of Linear Equations in Three Variables content was 75.6667. Twelve students were selected for the sample. After the test, the standard deviation decreased to 11.31639 with a standard error of the mean of 3.26676, down from 18.61309 before the test.

Table 5. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PRE and POS	12	.618	.032

The pre- and post-test correlation was 0.618 ($p < 0.0001$) according to the paired-samples correlation. This indicates that the two means, before and after problem-based learning (PBL) therapy, are significantly related. The following hypotheses are proposed:

- Null Hypothesis (H0): Students' understanding of System of Linear Equations in Three Variables content is not affected by the problem-based learning (PBL) model.
- Hypothesis 1: Students' understanding of System of Linear Equations in Three Variables content significantly increases when taught using the problem-based learning (PBL) model.

Table 6. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE - POS	-29.58333	14.63159	4.22378	-38.87980	-20.28687	-7.004	11	.000

The t-value is -7.004 with a significance level of 0.000, according to the Paired Sample Test. Accepting H1 means that the problem-based learning (PBL) technique significantly affects the learning outcomes of class X students in the System of Linear Equations in Three Variables material, since the significance level is 0.000, which is less than 0.05.

Discussion

In this preliminary study, there was no control or comparison group; instead, there was only one group, the experimental group. The purpose of this study was to evaluate the effectiveness of the Problem-Based Learning (PBL) approach on the academic achievement of grade 10 students at Al-Hidayah Islamic Senior High School. The analysis showed that the average student learning outcome after the test was 75.6667, an increase from 46.0833 before the test.

The significance level of $0.000 < 0.05$ was determined by comparing student learning outcomes with the t-table, which was 2.201, and t-count = -7004. Thus, it can be concluded that the Problem-Based Learning (PBL) approach in education has an impact

on the academic achievement of grade 10 students at Al-Hidayah Islamic Senior High School. We accept H1 and reject H0 based on the results.

Descriptive and inferential studies indicate that student learning outcomes and grades have improved dramatically. Therefore, the use of the Problem-Based Learning (PBL) model for 10th-grade students at Al-Hidayah Islamic High School has had a significant and beneficial impact on their academic achievement. The research results are supported by several previous studies that state that the problem-based learning model contributes to improving students' mathematics learning outcomes (Wilder, 2015; Ogunsola et al., 2021; Asanre et al., 2024).

One educational model that encourages learning through solving real-world problems is known as problem-based learning (PBL). By first posing a problem to the class, this learning model creates a student-centered information-seeking process. With a philosophical emphasis on students solving problems, PBL integrates instructional approaches and curricular perspectives. The goal of problem-based learning (PBL) is the effective acquisition and construction of knowledge. This differs from subject-based learning, where students are taught information and then asked to apply it to solve problems. PBL uses a tutorial system that incorporates small-group learning. As noted by Al-Thani and Ahmad (2025), the problem-based learning model includes posing questions or challenges, emphasizing interdisciplinary connections, conducting authentic investigations, producing and presenting work, and fostering collaboration.

Lutfiyah and Sulisawati (2019) emphasized that teachers consistently provide instruction and examples at every stage of learning. Teachers play a crucial role in this learning process, while students act as challengers. In this learning approach, teachers must be involved, while students play a passive role, simply listening, observing, and concentrating. This diminishes their creative potential. Furthermore, findings from initial observations indicate that educators use the same learning models and techniques even though the desired learning objectives differ. Such behavior negatively impacts student learning outcomes. Results remain significantly inadequate, with many students failing to achieve mastery, both individually and collectively. Consequently, learning objectives and concepts are not achieved due to teachers' inappropriate implementation of learning models in the classroom. To achieve this goal, we need a new educational methodology or framework.

The primary goal of mathematics education is to equip students with a comprehensive understanding of mathematical concepts and frameworks, as well as the ability to apply them in various disciplines and everyday situations (Maass et al., 2019). Mathematics learning outcomes are the results achieved by students during a specified learning period. Students' mathematics learning outcomes can be assessed through their exam scores (Fadillah et al., 2016).

The PBL model has a positive impact on students, as evidenced by Laamena et al. (2021), who concluded that this approach increases student engagement and problem-solving skills in mathematics, resulting in superior learning outcomes compared to traditional direct learning methods.

4. CONCLUSION

The research findings show that the Problem-Based Learning (PBL) model has a significant effect on the learning outcomes of class X students. The research shows that Class X students at Al-Hidayah Islamic High School who learned the Three-Variable Linear Equation System using the Problem-Based Learning (PBL) model had an average score of 46.0833 on the pretest and 75.6667 on the posttest. The significance value of the hypothesis test is less than 0.05, which indicates that $0.00 < 0.05$. As a result, H0 is rejected and H1 is accepted, which indicates a significant disparity in the mathematics learning outcomes of class X students at Al-Hidayah Islamic High School who use the Problem Based Learning (PBL) model.

As a recommendation, the research findings can serve as a reference for teachers implementing problem-based learning models to improve students' mathematics learning outcomes. Further research suggests the development of interactive media, particularly for systems of linear equations in three variables and other broader topics.

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