Effectiveness of Problem-Based Learning for Improved Learning Outcomes and Critical Thinking

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Abstract

Knowing students' learning outcomes and critical thinking abilities is crucial for effective instruction, resource allocation, and improving student learning across various subjects. This encourages testing of the effectiveness of problem-based learning in improving students' learning outcomes and critical thinking abilities. The aim of this research is to describe the impact of implementing the Problem-Based Learning model on improving learning outcomes and critical thinking skills in mathematics learning. This quasi-experimental research employed a pre-test, and post-test control group design involving 42 fifth grade elementary school students in one of the cities in Central Java, with 24 participants assigned to experimental group and 18 participants to control groups. Throughout a four-week duration, the experimental group received instruction utilizing Problem-Based Learning model, while the control group was taught applying traditional learning. Using tests of learning outcomes and critical thinking abilities, both groups were assessed before and after the intervention, and the data were analyzed using descriptive statistics and t-tests. The research findings indicate that Problem-Based Learning has a positive impact on mathematical learning outcomes and critical thinking, with improvements falling within the moderate category. In conclusion, there is a significant difference between classes using the Problem-Based Learning model and conventional classes. This finding enriches our understanding of the effectiveness of innovative teaching methods such as Problem-Based Learning in enhancing learning and critical thinking abilities in the context of mathematics education.

Keywords: critical thinking, education, learning outcomes, quasi experiment, problem-based learning

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INTRODUCTION

Mathematics is difficult due to its abstract nature, conceptual complexity, and the influence of attitudes, motivation, and learning habits (Purbaningrum et al., 2023; Retnawati et al., 2017; Febriyani et al., 2022). Parents, teachers, and peers influence students' beliefs that mathematics is difficult due to their priorities in performance over process and lack of motivation after failure (Purbaningrum et al., 2023). Students find mathematics difficult due to lack of concept understanding, calculating difficulties, selecting information, being deceived by distractors, and completing complex and non-integers test items (Retnawati et al., 2017). Mathematics is difficult due to a lack of competence in understanding mathematical concepts, which impacts students' attitudes and learning motivation (Febriyani et al., 2022).

Mathematics learning difficulties have a direct impact on students' mathematics learning outcomes (Nelson & Powell, 2018). When students face barriers in understanding mathematical concepts, they tend to have difficulty completing assignments and tests, which in turn negatively impacts their grades and academic performance. These difficulties can be caused by a variety of factors, including

an inability to understand abstractions, a lack of basic math skills, or even math anxiety (Wakeman et al., 2022; Acharya, 2017). As a result, students who experience difficulties learning mathematics often demonstrate lower learning outcomes compared to their peers who do not face similar obstacles. Thus, to improve mathematics learning outcomes, it is important to identify and overcome learning difficulties experienced by students through appropriate interventions, such as additional help, the use of more appropriate teaching methods, or a more individualized learning approach.

Difficulty learning mathematics is often closely related to a lack of critical thinking skills, because mathematics not only requires an understanding of abstract concepts but also the ability to analyze, evaluate and solve problems systematically (Ridwan et al., 2022; Susilo et al., 2021). Critical thinking skills enable students to identify patterns, make connections between concepts, and formulate effective problem-solving strategies (Basri et al., 2019). Without these skills, students may have difficulty understanding the logic behind mathematical processes, resulting in difficulty mastering the material and solving the problems given (Yeni & Herman, 2020; Kusumadewi & Retnawati, 2020). Therefore, developing critical thinking skills is essential to help students overcome difficulties in learning mathematics and improve their understanding of this subject.

The academic performance and critical thinking skills of students are still relatively low (Sarwanto et al., 2021; Ramos, 2018). Despite various educational reforms and initiatives aimed at improving these areas, many students continue to struggle with grasping fundamental concepts and applying critical analysis to solve problems. This situation highlights the urgent need for more effective teaching strategies and learning interventions to enhance students' understanding and cognitive abilities, ensuring they are better prepared for future academic and professional challenges (Biwer et al., 2020).

Problem Based Learning (PBL) has a significant role in fostering critical thinking skills and improving student learning outcomes (Manuaba et al., 2022; Dharma et al., 2020). PBL is a teaching method that focuses on using real and complex problems as a means to encourage students to learn and develop critical thinking skills. In PBL, students are placed in challenging situations where they must identify problems, gather information, analyze data, and develop effective solutions.

Current literature consistently underscores the positive impact of Problem-Based Learning (PBL) on both learning outcomes and critical thinking skills across various educational levels and disciplines (Lee & Son, 2021; Suhirman et al., 2020). Numerous studies have demonstrated that PBL fosters deeper understanding, greater retention of knowledge, and enhanced problem-solving abilities compared to traditional instructional methods. Additionally (Zhang & Hwang, 2022; Ishizuka et al., 2023; Pacheco et al., 2020), PBL is shown to significantly improve students' critical thinking by requiring them to analyze, evaluate, and synthesize information in the context of real-world problems. Innovative applications of PBL, including digital and blended learning environments, further amplify its effectiveness.

However, although there are studies on PBL, learning outcomes, and critical thinking, none have fully explored the topic of calculating time duration in fifth grade elementary school. Another novelty of this research is that it also evaluates the change in students' perceptions of mathematics from being intimidating to enjoyable with the implementation of PBL. To address the gap, the research implements the PBL model as a learning approach that has a tangible impact on improving learning outcomes. The implementation of PBL can stimulate students in developing and honing critical thinking skills. Therefore, the aim of this research is to describe the impact of implementing the Problem-Based Learning model on improving learning outcomes and critical thinking skills in mathematics learning.

METHODS

The research design used is quasi-experimental with a non-equivalent control group design. This study involves two groups, namely, the control class and the experimental class. The experimental class is given problem-based learning, while the control class receives regular instruction. However, both will be monitored to identify the results of the treatment given.

This research was conducted at a public elementary school in Karanganyar city, Central Java, Indonesia. The control class sample consisted of 18 students, and the experimental class sample consisted of 24 students. The assessment instruments included observation sheets and teacher interviews, as well as test instrument grids. Data collection techniques used were observation, interviews, tests, and documentation. The test questions were in the form of 20 multiple-choice questions. Data analysis was conducted using a comparison of pre-test and post-test scores. The data analysis techniques included statistical calculations of mean, highest and lowest values, normality tests, homogeneity tests, n-gain tests, and average tests using independent sample t-tests.

RESULTS AND DISCUSSION

The implementation of the problem-based learning model in teaching time duration calculation aims to analyze the improvement and differences in learning outcomes and critical thinking skills of elementary school students. Firstly, a pretest was conducted for each class to determine the initial competencies of the students. In the second stage, the experimental class was given treatment using the problem-based learning model, while the control class received conventional or regular instruction. After the treatment was applied to both classes, the third stage involved administering a post-test to both classes to measure learning outcomes and critical thinking skills. The fourth stage involved conducting an analysis using the independent sample t-test. The final stage was analyzing the obtained data and drawing conclusions.

A normality test is used when the sample size is less than 30, to determine whether the error term approximates a normal distribution. Data can be considered normally distributed if the null hypothesis (H_0) is accepted with a significance level greater than 5% or 0.05. Below are the results of the normality test. Here are the normality test data for the learning outcomes and critical thinking skills of the experimental and control classes.

Table 1. Normality Test Results

Class	Learning Outcome			Critical Thinking		
	Statistik	df	Sig.	Statistik	df	Sig
Experiment	.133	24	.200	.913	24	.131
Control	.179	18	.134	.911	18	.090

The data in Table 1 shows that the learning outcomes and critical thinking scores of students in the experimental and control classes are normally distributed. The analysis of the research results was obtained from the recapitulation of scores in both classes. The scores were examined and processed to obtain the average, highest, and lowest scores. Below are the results of the analysis of the pretest and posttest scores for the control and experimental classes.

Table 2. Results of the mathematics score calculation

No	Description	Control Class		Experimental Class	
		Pretest	Posttest	Pretest	Posttest
1	Average	57,50	75,27	57,08	83,75
2	Highest Score	70	85	70	100
3	Lowest Score	45	55	40	70

The results in Table 2 show that the lowest score in the control class is 45, while the experimental class has a lowest score of 40. After the experimental class students received treatment using the problem-based learning model, the lowest score in the experimental class increased to 70, with the highest score being 100 and an average score of 83.75, achieving a 100% success rate. The findings are supported by research from Ramadhany et al. (2023), which states that classes using problem-based learning have a higher effect size compared to conventional teaching models. The increase in the average mathematical results on the topic of calculating time duration indicates that the model applied in the classroom has a positive impact on learning outcomes and critical thinking.

Based on the statistical analysis involving the independent sample t-test, the experimental class obtained a t-value of 3.199 and a t-table value of 1.681. According to the decision-making criterion, if t-value > t-table, then H_0 is rejected and Ha is accepted. This indicates that the implementation of the problem-based learning model on the topic of calculating time duration has a positive impact on improving the learning outcomes and critical thinking skills of elementary school students. The analysis results from several researchers (Aryani et al., 2023; Darmiyati et al., 2023; Iswanto et al., 2023; Mulyanto et al., 2018) concluded that there is an improvement from the implementation of the problem-based learning model on students' mathematical learning outcomes and the average learning scores. According to research (Mulyanto, 2018), the problem-based learning model showed a significant improvement in mathematics learning outcomes and critical thinking skills of elementary school students.

Based on observations, interviews, and the calculated data results, there is an improvement in the learning outcomes and critical thinking skills of students when the teacher uses the problem-based learning model on the topic of calculating time duration. The problem-based learning model has been researched since the 1990s, and its use is very promising for exploring and developing teaching methods for 21st-century students (Caswell, 2019). In line with the thoughts of Alpaslan & Yalvac (2023), the problem-based learning model utilizes a problem that has been oriented towards students, providing opportunities to develop, enhance, and hone both academic and non-academic values. The results of the study conducted by Aprila & Fajar (2022) concluded that the use of the problem-based learning model can be an alternative for delivering mathematics material in the classroom because it teaches students to think critically, collaborate, and improve communication skills.

The N-Gain test is necessary to measure the difference between the pretest and posttest scores in the experimental class, to determine whether there is an improvement after the treatment with the problem-based learning model. The data obtained from the N-Gain test for the experimental and control classes is shown in Table 3.

Table 3. Results of the n-gain calculation for learning outcomes

Class	Pretest	Posttest	N-gain	Criteria
Experiment	57,08	83,75	0,62	Medium
Control	57,50	75,27	0,42	Medium

In Table 3, a difference in the average N-Gain between the two classes can be seen. The results show that the experimental class obtained a score of 0.62 with a medium criterion, while the control class obtained a score of 0.42, also with a medium criterion. This proves that the implementation of the problem-based learning model on the topic of calculating time duration is more effective compared to the use of the conventional model. These findings are in line with the research by Butar Butar et al. (2022), which indicates that the problem-based learning model has a positive and significant impact on learning outcomes and can be an effective breakthrough to enhance students' understanding in mathematical learning. Findings from research (Adawiyah et al., 2022; Aries, 2022; Supriana et al., 2023) show that students' learning outcomes are higher when the learning process uses the problem-based learning model compared to the conventional model. This is because, theoretically, problem-based learning is an innovative learning model where the learning process is centered on the students (Supriana et al., 2023).

Critical thinking skills can be improved through the implementation of the problem-based learning model (Agustina et al., 2018). The statistical data from the N-Gain test for students' critical thinking, which shows the difference between the experimental and control classes, can be seen in Table 4.

Table 4. Results of the n-gain calculation for critical thinking

Class	Pretest	Posttest	N-gain	Criteria
Experimental	57,91	84,37	0,63	Medium
Control	57,77	79,33	0,49	Medium

The results of the N-Gain test data for critical thinking in the control class showed an average score of 0.49, which falls into the medium category, while the experimental class had an average score of 0.63, also in the medium category. This indicates that the implementation of the problem-based learning model in the experimental class on the topic of calculating time duration led to an improvement, whereas the control class did not experience a significant increase. This is in line with the research by Ramadhanti et al. (2022), which states that by utilizing an appropriate learning model, students can be encouraged to be active when given problems and to solve problems using reasoning and critical thinking, allowing them to express their creativity.

The average difference test was conducted to determine the difference in the improvement of students' learning outcomes. The comparison test was performed using the t-test formula, with the criterion that H_0 is rejected if t-value > α with α = 0.05. The results of the difference in the improvement of students' learning outcomes are shown in Table 5.

Table 5. Results of the t-test for learning outcomes

Class	$\bar{x}_i$	S	Df	α	t-value	t-table	Description
Experiment Control	0,62	0,217	40	5%	3,199	1,681	H_0 rejected

Table 5 shows that t-value > t-table or 3.199 > 1.681, thus Ha is accepted, meaning there is a difference in the improvement of learning outcomes between the class given treatment using the problem-based learning model and the class taught using conventional methods. The results of the research conducted by Aprila & Fajar (2022) concluded that the use of the problem-based learning model can be an alternative for delivering mathematics material in the classroom because it teaches students to think critically, collaborate, and improve communication skills, thereby having a positive impact on improving learning outcomes. In line with the thoughts of Alpaslan & Yalvac (2023), the problem-based learning

model utilizes a problem that has been oriented towards students, providing opportunities to develop, enhance, and hone both academic and non-academic values. The results of the comparison test scores for students' critical thinking skills using the t-test formula can be seen in Table 6.

Tabel 6. The results of the t-test for critical thinking

Class	$\bar{x}_i$	S	dk	α	t_{hitung}	t_{tabel}	Description
Experiment Control	0,62	0,217	40	5%	2,234	1,681	H_0 rejected

According to the decision-making criterion, if t-value > t-table, the data differs significantly. This means there is a difference in critical thinking between students who were given treatment using the problem-based learning model and those taught using conventional or lecture methods. The implementation of the problem-based learning model in the mathematics learning process has a positive impact and hones critical thinking skills. Students pay more attention to the teacher's directions, stay focused on the lesson, appear active and very enthusiastic in class, participate in discussions, and actively answer the teacher's questions (Khairunisa et al., 2023). In line with the findings of Ulger (2018), to face the 21st-century learning paradigm, students are required to have critical thinking skills, master technology, apply theoretical knowledge in everyday life, and collaborate.

CONCLUSION

The implementation of the Problem-Based Learning (PBL) model in elementary school mathematics significantly improves learning outcomes and critical thinking skills. The research demonstrated that students in the experimental group, who were taught using the PBL model, showed considerable improvement in their mathematical abilities and critical thinking compared to the control group that received conventional instruction. The findings indicate that PBL is an effective teaching strategy for enhancing students' understanding of mathematical concepts and fostering critical thinking. This is supported by the statistical analysis, which showed a significant difference in the performance of students taught with PBL. The study's results are consistent with previous research, confirming that PBL can be a valuable alternative to traditional teaching methods in promoting better academic performance and cognitive development.

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