Jurnal Pendidikan Matematika
ISSN-p 2086-8235 | ISSN-e 2597-3592
Vol. 16, No. 2, July 2025, Pages: 154-163, Doi: https://doi.org/10.36709/jpm.v16i2.304
Available Online at https://jpm.uho.ac.id/

Discovery Learning and Mathematical Problem-Solving: Evidence from Elementary Education Classrooms

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Abstract: Problem-solving ability is one of the essential higher-order thinking skills (HOTS) in mathematics education. However, many elementary students still struggle to apply this skill effectively due to learning models that do not actively involve them in the process. This study aims to determine the effectiveness of the Discovery Learning model on students' mathematical problem-solving abilities. The research used a quantitative approach with a pretest-posttest control group design involving fourth-grade students. The sample consisted of 56 students selected through random sampling, divided into control and experimental classes. Data were collected using validated problem-solving tests and observations of learning implementation. The results showed a significant effect of the Discovery Learning model on students' problem-solving abilities in spatial geometry. The effect was evidenced by the higher average posttest score of the experimental class (70.2) compared to the control class (51), supported by the t-test result (sig. 0.000 < 0.05). Thus, the Discovery Learning model is proven effective in improving mathematical problem-solving skills and can be recommended as an alternative active and constructive learning strategy.

Keywords: discovery learning model; mathematics; problem-solving skills; spatial geometry.

INTRODUCTION

Education plays a crucial role in honing 21st-century skills and optimizing higher-order cognitive abilities. In today's learning environment, students are expected to develop critical thinking, creativity, and problem-solving skills so they can be effectively applied in everyday life. These three skills are known as higher-order thinking skills (Mardhiyah et al., 2021). Problem-solving skills are an essential component in learning because they enable students to analyze, identify, and formulate solutions to appropriate actions in solving problems (Novita et al., 2023).

Mathematics is taught as a vital tool for solving problems, serving as a foundation for the development of science and technology, and as a way of representing various real-world situations (Elfiyani, 2024). In everyday life, mathematical concepts are applied, for example, when calculating shopping needs, measuring the area of a room for ceramic tile installation, estimating travel time, or comparing discounted prices. This demonstrates that mathematical understanding is not only needed in the classroom but also for logical and efficient decision-making in various situations. Mathematics learning also serves to hone critical, logical, analytical, and systematic thinking skills (Narawidia et al., 2022). Therefore, mathematics learning in elementary schools needs to focus not only on mastering concepts but also on developing numeracy literacy and higher-order thinking skills, such as problem-solving, critical thinking, and collaboration (Maharbid, Awiria, et al., 2024). Problem-solving skills are highly significant in the learning process because they encourage students to identify and understand problems, design appropriate solution strategies, implement solution steps, and evaluate the results achieved. This problem-solving ability is in accordance with Polya's (1973) indicators, which are also used as steps in solving problems (Nasution & Hsb, 2022). From primary to secondary school level, mathematics learning is one of the essential components that needs to be introduced and instilled in students (Sulastri et al., 2024).

However, research by (Damanik & Handayani, 2023) shows that students' ability to solve mathematical problems remains low. This is reflected in the 2022 PISA data, which

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recorded an average mathematics score of only 366 for Indonesian students, far below the OECD average of 472 (OECD, 2023). These results indicate that Indonesian students have difficulty applying mathematical concepts in the context of solving real-life problems (Sriwahyuni & Maryati, 2022). (Sofian et al., 2024) also reported that students have difficulty solving problems to the final solution. Research by (Arrosyad et al., 2023) found that some students had difficulty determining the correct calculation steps, while others did not understand the core of the problem due to a lack of reading accuracy.

Interviews with fourth-grade elementary school teachers support these findings, stating that approximately 13 (45%) of 30 students experienced difficulty solving word problems. Teachers have tried various learning models, such as inquiry, problem-based learning, and project-based learning, but the results have not been optimal in terms of students' problem-solving abilities. Teachers also noted that students often understand the concept of the problem but are unable to follow systematic steps when solving the problem. Students often struggle to identify important information in word problems, such as size, quantity, or units. Students immediately answer without first understanding the problem or without developing steps to solve it. Students often make arithmetic errors, even though they understand the concept. Before formulating and selecting an appropriate learning model, educators need to have a comprehensive understanding of their students' characteristics (Widiawati et al., 2023).

Some factors contributing to this problem include limited teacher competency in developing engaging and effective learning models (Puspitasari, 2021). Many teachers still employ traditional teacher-centered lecture methods (Hamdani et al., 2021). This discourages students from actively participating, resulting in diminished critical thinking and problem-solving skills (Lismaya, 2019). To address this issue, a learning model that can enhance students' problem-solving skills is needed (Anggraini et al., 2022). Implementing a learning model that transforms the teaching process by utilizing experience or independent exploration as a means of learning activities is one model for improving statistical literacy competency and student self-confidence in the learning context (Maharbid, Awiria, & Markum, 2024). One relevant learning model to address this is Discovery Learning, as it actively engages students in discovering knowledge, making learning more meaningful and contextual (Lestari, 2020). Research by (Muhammad et al., 2023), also shows that implementing the discovery learning model can significantly improve students' problem-solving abilities in mathematics learning. This results in a deeper understanding and a more meaningful learning experience (Setyowati et al., 2018). Discovery learning also trains students to solve problem-based problems through steps such as providing stimulation, identifying problems, collecting data, processing data, proving, and drawing conclusions (Jana & Fahmawati, 2020). In this model, the teacher acts as a facilitator, while students actively explore solutions (Nurdiana, 2019).

The results of the study (Anggraini, 2023) show a significant effect of discovery learning on students' mathematical problem-solving abilities. Furthermore, research by (Anizzulfa et al., 2023), also concluded that the discovery learning model influences students' mathematical problem-solving abilities at the junior high school level. Furthermore, (Ramadhani, 2021), research stated that the Discovery Learning approach has successfully improved student learning outcomes. However, similar research specifically examining the influence of the Discovery Learning model on geometric shapes in elementary schools is still very limited. This creates a research gap that needs to be filled, as geometric shapes have visual and spatial characteristics that are suitable for the discovery learning approach.

Considering the limitations of previous research, this study aims to analyze the influence of the Discovery Learning model on elementary school students' problem-solving abilities in spatial geometry. The results are expected to contribute scientifically to enriching mathematics learning strategies that encourage problem-solving skills, particularly in spatial geometry in elementary school.

METHODS

This study uses a quantitative approach with a pretest-posttest control group design. This study was conducted at the elementary school level of fourth-grade students, consisting of three classes: IV A, IV B, and IV C. The research sample amounted to 56 students determined using random sampling techniques, namely class IV A as the control group and class IV B as the experimental group that received the Discovery Learning model learning treatment. Data were collected through essay tests of problem-solving abilities in the form of pretests and posttests, observations of learning activities, and documentation of the implementation of the study. The research instrument was developed and tested for validity and reliability through the Pearson Product-Moment correlation test and reliability analysis using Cronbach's Alpha in the trial class, namely IV C.

The research procedure includes preparation stages such as initial observation, sample determination, preparation of instruments and teaching materials, as well as testing the validity and reliability of the instruments. The implementation stage of the research includes administering a pretest, implementing the discovery learning model in the experimental class, observing teacher activities, and administering a posttest. The pretest and posttest each consisted of 5 essay-style questions. The implementation of the discovery learning model was carried out based on the syntax, namely providing stimulation, identifying problems, collecting data, processing data, proving, and drawing conclusions. Data analysis was carried out through prerequisite tests, namely normality and homogeneity tests, and hypothesis testing (t-test) using the independent sample t-test technique to identify significant differences between the pretest and posttest results of the two groups. The observation of teacher implementation in the learning process was arranged according to the discovery learning syntax. The assessment categories for observation activities were scores of 86% - 100% (very good category), scores of 71% - 85% (good category), scores of 55% - 70% (fair category), and 0% - 54% (sufficient category).

The findings of this study serve as the basis for formulating conclusions regarding the effect of the discovery learning model on students' mathematical problem-solving abilities in learning spatial geometry. The indicators used in this study are Polya's 1973 problem-solving ability indicators, which include understanding the problem, developing a solution plan, implementing the plan, and reviewing the results

RESULTS AND DISCUSSION

The research was conducted over three meetings, including a pretest and posttest. In the first meeting, a pretest was given to the experimental and control classes to determine students' initial abilities. In the second meeting, learning activities were carried out in both the experimental class using the discovery learning model and the control class using the conventional model. The material taught included the shape, characteristics, and nets of cubes and cuboids. In the third meeting, the material taught was the volume and area of cuboids and cubes. The experimental class received learning intervention through the application of the discovery learning model combined with the habit of solving problems based on problem-solving indicators according to Polya. The learning process was carried out systematically following the stages of the Discovery Learning model, which include providing stimulus, identifying problems, collecting information, processing data, applying processes, and drawing conclusions.

Indicators of problem-solving abilities that are used as stages in solving problems according to Polya's theory (1973) in the article by (Silvi, Witarsa & Ananda, 2020), include understanding the problem, making a solution plan, implementing the plan, and re-examining the results. These indicators are used to compile essay test instruments in the form of pretests and posttests. The question indicators that have been compiled by researchers are in accordance with the problem-solving indicators according to Polya's theory (1973). The first question item has a question indicator form, namely presented with an image, students are able to decide which objects are included in the form of a geometric shape. The second question item is presented with a story problem; students can assess the suitability of the characteristics of a cube with a given situation and provide logical justification for the characteristics of the geometric shape. The third question item is presented with an image; students can create a net pattern from a cube geometric shape. The fourth question item is presented with an image, students can solve the area of a cube geometric shape according to the length of the side determined by themselves. The fifth question item is presented with an image; students can compare the size of the two different volumes of geometric shapes.

The question indicators show the question grid on mathematical problem-solving skills used for the pretest and posttest. The instrument was applied to two groups: class IV B as the experimental class receiving instruction using the discovery learning model, and class IV A as the control class receiving conventional learning. The questions presented consisted of five essays designed to suit students' cognitive levels and to hone their problem-solving skills. The material focused on the geometric shapes of cubes and cuboids.

Table 1. Pretest and Posttest Results of Discovery Learning Model

No.	Score	Discovery Learning Model	
		Pretest	**Posttest**
1.	Number of Students	30	30
2.	Highest Score	92	95
3.	Lowest Score	28	47
4.	Mean Score	57,60	70,20
5.	Standard Deviation	17,514	12,607

Table 1 shows a significant difference in the pretest and posttest results for the discovery learning model. This is evident from the average pretest score of 57,60 and posttest score of 70,20. This change occurred because students received the discovery learning model for spatial geometry.

Table 2. Pretest and Posttest Results of Conventional Model

No.	Score	Conventional Model	
		Pretest	***Posttest***
1.	Number of Students	26	26
2.	Highest Score	70	70
3.	Lowest Score	25	30
4.	Mean Score	49,12	51,00
5.	Standard Deviation	13,264	11,723

Table 2 shows the pretest and posttest results for the control class, which experienced only slight changes. This is evident from the average pretest score of 49,12 and posttest score of 51,00. The learning conducted in the control class used a conventional model.

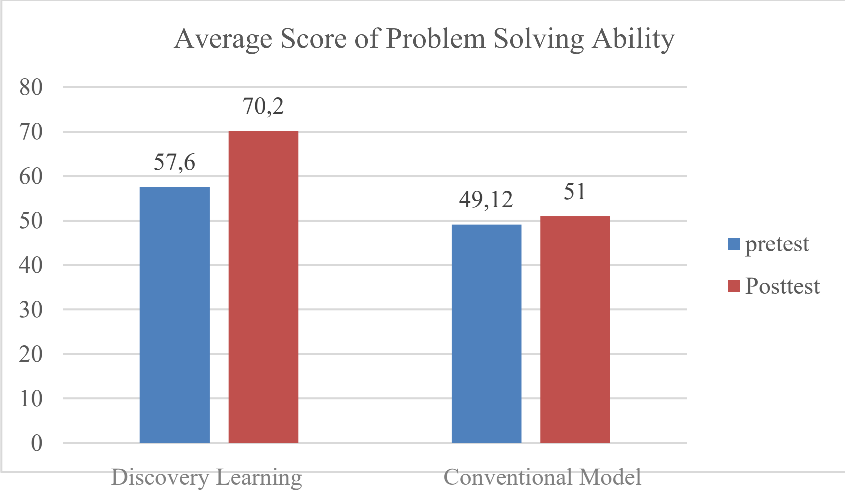

Figure 1. Comparison Graph of the Average Values of the Discovery Learning Model and the Conventional Model

Figure 1 shows the difference in the average score of students' mathematical problem-solving ability between the discovery learning model and the conventional model. The most significant increase was seen in the experimental class treated with the Discovery Learning model, which was 12.6 points. In contrast, the control class only experienced a small increase of 1.88 points. This indicates that the application of the Discovery Learning model has a positive effect on improving the mathematical problem-solving ability of fourth-grade students on the topic of geometric shapes. After the pretest and posttest were conducted on both groups, a normality test was conducted to evaluate whether the data distribution met statistical requirements. This test uses a significance level of 5%, where data is considered normally distributed if the significance value (p) > 0.05.

Table 3. Data Normality Test Results

		Kolmogorov-Smirnov			
Data	**Class**	**Statistic**	**Df**	**Sig.**	**Description**
Pretest	Conventional	.140	26	.200*	Normally Distributed
Posttest		.125	26	.200*	Normally Distributed
Pretest	Discovery Learning	.135	30	.175*	Normally Distributed
Posttest		.073	30	.200*	Normally Distributed

The normality test used in this study was the Kolmogorov-Smirnov test with the help of SPSS. According to (Biu, Nwakuya & Wonu, 2020), Kolmogorov-Smirnov is more appropriate for large samples or more than 40. In this study, the sample used was 56 or ≥ 40. Based on Table 3, it can be concluded that the sig. (p value) of the pretest and posttest > 0.05. So it can be said that the data is normally distributed.

Table 4. Homogeneity Test Results

		Test of Homogeneity of Variance		
Indicator	**Data**	**Class**	**Sig (*Based on Mean*)**	**Descripstion**
Problem-Solving Ability	*Pretest*	Conventional Discovery Learning	0.116	Homogeneous
	Posttest	Conventional Discovery Learning	0.764	Homogeneous

The homogeneity test aims to determine whether the data in both groups come from a homogeneous population. This study used the Levene statistical test using SPSS. The basis for the homogeneity test is that if the significance value (sig) based on the mean is > 0.05, then the data variance is homogeneous. Table 4 presents the results of the homogeneity test based on the pretest and posttest scores for the discovery learning model and the conventional model. Based on the results of the Test of Homogeneity of Variances, the pretest significance value was 0.116 > 0.05, indicating that the pretest data in both groups were considered homogeneous. Furthermore, the posttest significance value was 0.764 > 0.05, indicating that the posttest data in both groups were also considered homogeneous. Furthermore, the normalized and homogeneous data were then subjected to hypothesis testing using the independent samples test technique. The results of the hypothesis test are presented in Table 5 below.

Table 5. Independent Samples Test Hypothesis Test Results (T-Test)

Independent Samples Test				
Indicator	**Data**	**Class**	**Sig (2-*Tailed*)**	**Description**
Problem-Solving Ability	*Pretest*	Conventional Discovery Learning	0.093	Ho accepted
	Posttest	Conventional Discovery Learning	0.000	Ha accepted

Table 5 shows the hypothesis test measured using the Independent Samples Test (SPSS) analysis technique. The decision-making criteria are: if the sig (2-tailed) value is <0.05, then the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted, indicating a significant effect, assuming the average values of the discovery learning model and the conventional model are not equal. Conversely, if the sig (2-tailed) value is > 0.05, then the null hypothesis (Ho) is accepted and the alternative hypothesis (Ha) is rejected, indicating no significant effect, assuming the average values of the discovery learning model and the conventional model are equal.

The table 5 shows the results of the pretest in the experimental class (IV B) and the control class (IV A), with a sig (2-tailed) of 0.093 > 0.05, indicating that Ho is accepted and Ha is rejected, assuming the average values of the discovery learning model and the conventional model are equal. This occurred because in the pretest, the two groups tested had not received the discovery learning model treatment in the discovery learning model or the conventional model in the conventional model. Therefore, it is said that both groups had the same average scores, or both groups had the same initial ability.

Furthermore, the hypothesis test on the posttest results in the discovery learning model and the conventional model was seen from the sig (2-tailed) 0.000 < 0.05, meaning Ho was rejected and Ha was accepted, assuming the average scores of the discovery learning model and the conventional model were not the same. This occurred because each group had received treatment such as the discovery learning model in the discovery learning model and the conventional model, resulting in a difference in the average scores between the two groups. The discovery learning model had a higher average score than the conventional model. It can be concluded that implementing the discovery learning model can significantly impact elementary school students' problem-solving abilities in spatial geometry.

Table 6. Observation Results of Teacher Implementation in Learning

Meeting	Maximum Score	Score Obtained	Final Score	Category
M-1	84	74	88	Very Good
M-2		78	93	Very Good

Table 6 shows the observation sheet used to measure the achievement of learning objectives in the discovery learning model. Observation results from two meetings showed that teacher implementation was 88%, with a very good assessment criteria, in the first meeting, and 93% in the second meeting, with a very good assessment criteria. This indicates that the learning process was proceeding very well and according to plan, although several aspects still needed improvement.

The significant improvement in problem-solving skills in the class that used the experimental discovery learning model indicates that this approach can create a more meaningful learning process. In mathematics learning, particularly in geometric shapes, students are not only required to memorize formulas but also to understand spatial concepts visually and logically. The discovery learning model provides space for students to construct their understanding through exploration, observation, and proof of objects or problems presented in real-world contexts. This model contrasts with the conventional approach in the control class, which emphasized lectures and practice problems, resulting in low student engagement in critical thinking.

Practically, the effectiveness of discovery learning in this study can be attributed to its implementation stages, which actively involve students, starting from providing stimuli, identifying problems, collecting and processing data, to proving and drawing conclusions. At each stage, students are trained to thoroughly read and understand the problem, choose appropriate problem-solving strategies, and reassess the logic of their answers. This strongly supports the development of problem-solving ability indicators according to Polya (1973). Conversely, in the control class, the teacher was more dominant as the center of information, and the students' thinking process was passive, thus not stimulating the emergence of in-depth problem-solving abilities. This explains why the increase in posttest scores in the experimental class was much higher than in the control class.

These findings align with research by (Nasution & Hsb, 2022; Haryuti, 2022), which also showed significant differences between experimental and control classes in problem-solving skills. Similar findings were also reported by (Syawaludin et al., 2022) who found that classes using discovery learning demonstrated greater improvement in problem-solving skills compared to control classes using conventional learning. Furthermore, a study by (Jana & Fahmawati, 2020) found that the discovery learning model can develop higher-order thinking skills (HOTS), particularly in solving mathematical word problems that require analysis and reasoning.

Thus, a learning model like discovery learning not only encourages higher learning outcomes but also develops more complex cognitive skills. This model is particularly well-suited for visual and conceptual materials such as geometric shapes, as it allows students to construct concepts actively and reflectively. Therefore, this model is worth recommending as a strategic alternative for improving students' problem-solving abilities, particularly at the elementary school level, which lays the foundation for developing mathematical thinking

CONCLUSION

Based on the research results, it can be concluded that the application of the discovery learning model in mathematics learning on spatial geometry material in grade IV elementary school students is effective in improving students' problem-solving abilities. This can be seen from the higher average posttest score in the discovery learning model (70.2) compared to the conventional model (51). The results of the hypothesis test (t-test) on the posttest showed a significance value of 0.000 < 0.05, so the conclusion is that there is a significant influence of the use of the discovery learning model on the problem-solving abilities of grade IV elementary school students on spatial geometry material.

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