

The Effectiveness of Guided Discovery Learning Assisted by Desmos on Students' Mathematical Problem-Solving Ability

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Abstract: This study aims to examine the effectiveness of Guided Discovery Learning (GDL) assisted by the Desmos application in terms of junior high school students' mathematical problem-solving ability. This study employed a quasi-experimental method with a non-equivalent pretest-posttest control group design. It was conducted at a public junior high school in Yogyakarta. The sample consisted of students from two eighth-grade classes randomly selected from seven eighth-grade classes. Class VIII-F was assigned as the experimental group and received the Guided Discovery Learning model assisted by Desmos. In contrast, Class VIII-G was assigned as the control group and received the expository learning model. Data were collected using a mathematical problem-solving ability test in the form of essay questions based on Polya's problem-solving stages, which had been tested for validity and reliability. Data were analyzed using a one-sample t-test, a one-sample proportion test, and Analysis of Covariance (ANCOVA). The results indicate that the average mathematical problem-solving ability of students in the experimental class significantly exceeded the KKTP ($t = 8.01$; $p < 0.05$), the proportion of students who met the KKTP threshold exceeded 75% ($Z = 2.265$; $p = 0.012$), and Guided Discovery Learning assisted by Desmos was more effective than the expository learning model in terms of mathematical problem-solving ability after controlling for pretest scores ($F = 8.684$; $p = 0.005$; $\eta_p^2 = 0.14$). In addition, students in the experimental class demonstrated better performance at each stage of problem-solving based on Polya's framework. Thus, Guided Discovery Learning assisted by Desmos is effective for junior high school students' mathematical problem-solving ability.

Keywords: guided discovery learning, desmos, mathematical problem-solving ability, quasi-experimental study.

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■ INTRODUCTION

Mathematical problem-solving ability refers to the ability to solve challenging situations through the stages of understanding the problem, planning a solution, carrying out the plan, and reviewing the results obtained (Polya, 1973; Rahayu et al., 2024). The National Council of Teachers of Mathematics (NCTM) identifies problem-solving ability as one of the five process standards in mathematics learning. It emphasizes that "problem solving is an integral part of all mathematics learning" (NCTM, 2000). Mathematical problem-solving ability enables students to apply

mathematical concepts and principles to solve problems in both mathematical contexts and everyday life (Jean & Ellissi, 2025; Kurniyawati et al., 2019). In mathematics, problem-solving ability refers to the logical, systematic thinking process students use to understand, plan, solve, and evaluate a mathematical problem.

Low levels of mathematical problem-solving ability remain a challenge in mathematics learning. This aligns with the results of the Program for International Student Assessment (PISA) 2025, which showed that the average mathematics score of Indonesian students was only 364, a

two-point decrease from the previous PISA results, and that only approximately 16.93% of students reached the minimum proficiency level (OECD, 2026). Low levels of mathematical reasoning and problem-solving ability among junior high school students have also been identified in the Special Region of Yogyakarta (DIY), where eighth-grade students continue to experience significant difficulties when solving higher-order reasoning problems based on TIMSS standards (Jailani & Wulandari, 2017). Several studies have shown a significant relationship between the instructional models teachers use and junior high school students' mathematical problem-solving ability (Ovadiya, 2025; Yusri, 2018). Specifically, low mathematical problem-solving ability is often associated with classroom instructional practices that emphasize content delivery and practice exercises without giving students sufficient opportunities to explore mathematical concepts independently (Dewi & Wulandari, 2025). Students are more often asked to apply previously presented formulas than to explore mathematical concepts or develop solution strategies independently. Consequently, students become accustomed to following algorithmic procedures and tend to memorize rather than understand, which makes it difficult for them to deal with non-routine problems that require creativity and flexible thinking (Suryani et al., 2020). Therefore, a learning model is needed that can facilitate students' active engagement in constructing their understanding of mathematical concepts, ultimately enhancing their mathematical problem-solving ability.

One learning model that has the potential to develop mathematical problem-solving ability is Guided Discovery Learning. This model extends Discovery Learning by integrating concept discovery with teacher guidance, minimizing misconceptions and disorganized knowledge (Arung et al., 2022; Bruner, 1977).

In Guided Discovery Learning, students play an active role in discovering concepts through exploration, investigation, and collaboration. At the same time, the teacher acts as a facilitator, guiding the learning process (Andreas et al., 2019). Through this process, students do not merely memorize formulas but also understand how concepts are derived, examined, and applied to solve problems, thereby enabling higher-order thinking skills to develop systematically. These findings are supported by a study by Kokeb et al. (2025), which showed that Guided Discovery Learning resulted in better mathematical problem-solving ability than conventional learning.

The implementation of Guided Discovery Learning can be optimized through the use of educational technology. Technology enables students to visualize abstract mathematical concepts, making them easier to understand while also increasing student engagement in learning and problem-solving (Chechan et al., 2023). One tool is Desmos, a web-based mathematics application that provides interactive visualizations of various mathematical concepts (Chorney, 2021; Ferianto et al., 2023; Machado, 2023). In Guided Discovery Learning, Desmos supports students' exploration of mathematical objects, pattern observation, conjecture testing, and concept discovery through dynamic visual representations. This aligns with a meta-analysis by Ulya et al. (2024), which found that technology-based mathematics learning improves students' problem-solving ability. More specifically, technology provides a learning environment that fosters problem-solving skills (Davor et al., 2026).

One mathematics topic that requires strong visualization skills is three-dimensional shapes with flat surfaces. In this topic, students still frequently struggle to solve problems, particularly because they tend to memorize formulas without developing a deep understanding of the underlying concepts, making it difficult for them to determine

appropriate solution strategies (Aboagye et al., 2021; Usman et al., 2020). These characteristics make three-dimensional shapes with flat surfaces suitable for instruction through Guided Discovery Learning, as students are not directly given formulas for surface area and volume but are guided to discover the concepts through exploration. In addition, using the Desmos application to teach three-dimensional shapes with flat surfaces is relevant because Desmos provides 3D graphing features that let students visualize shapes interactively, rotate objects, view them from different perspectives, and dynamically explore changes in surface area or volume. Such interactive visualizations support the exploration and discovery stages of Guided Discovery Learning, suggesting that integrating the learning model, the Desmos application, and the topic of three-dimensional shapes with flat surfaces can improve students' mathematical problem-solving ability (Ferianto et al., 2023).

Various studies have demonstrated that Guided Discovery Learning and the use of technology have positive effects on students' mathematical problem-solving ability. Simamora et al. (2018) and Kokeb et al. (2025) reported that Guided Discovery Learning can improve students' problem-solving ability, while Ulya et al.'s (2024) meta-analysis showed that integrating technology also positively affects this ability. Nevertheless, research integrating Guided Discovery Learning with the Desmos application remains relatively limited. This study examines the effectiveness of Desmos-assisted Guided Discovery Learning in developing students' mathematical problem-solving ability.

The research questions are as follows. Is students' ability to understand the problem in the class implementing Desmos-assisted Guided Discovery Learning significantly higher than that in the control class?

Is students' ability to devise and carry out appropriate strategies in the class implementing

Desmos-assisted Guided Discovery Learning significantly higher than that in the control class?

Is students' ability to evaluate the solution in the class implementing Desmos-assisted Guided Discovery Learning significantly higher than that in the control class?

Based on the theoretical framework and previous empirical findings, this study proposes the following hypotheses.

Students' ability to understand the problem in the class implementing Desmos-assisted Guided Discovery Learning is significantly higher than that in the control class.

Students' ability to devise and carry out appropriate strategies in the class implementing Desmos-assisted Guided Discovery Learning is significantly higher than that in the control class.

Students' ability to evaluate the solution in the class implementing Desmos-assisted Guided Discovery Learning is significantly higher than that in the control class.

■ METHOD

Research Design

This study employed a quasi-experimental method with a non-equivalent pretest-posttest control group design. The experimental class received the Guided Discovery Learning model assisted by Desmos, while the control class received the conventional learning model. In this study, Guided Discovery Learning assisted by Desmos was implemented through several phases.

In the problem identification phase, the initial step in concept exploration, students were presented with a visual cognitive conflict through Desmos, which helped them formulate and communicate initial hypotheses using the multiple-choice and answer box features. In the data collection phase, the teacher guided students to collect data by answering questions provided in Desmos, using the table and Polypad features to help students determine and apply problem-

solving strategies. In the data processing phase, students explored three-dimensional shapes using the Polypad, slider, and split features, which helped them discover patterns in the relationships among flat surfaces, surface area, and volume without memorizing formulas, as they constructed knowledge through exploratory visualization.

In the tentative conclusion phase, the open-ended/free-response feature allowed students to digitally record their reasoning and justifications, which they then discussed collectively. In the verification phase, the check box and card sort features were used to verify students' discoveries. In the generalization phase, the answer box feature in Desmos was used to enable students to apply their findings to solve mathematical problems. Meanwhile, the conventional learning model referred to the learning model commonly used at the school where the study was conducted. Specifically, the conventional learning model used in this study was the expository learning model.

Participants

The study was conducted at a public junior high school in Yogyakarta during the second semester of the 2025/2026 academic year. The sample consisted of students from two eighth-grade classes randomly selected from seven eighth-grade classes, for a total of 64 students (32 students per class) in the initial sample. All students in the initial sample took the pretest. Based on demographic and initial academic data, the study sample is described as follows. The students were 14–15 years old, with a balanced gender distribution of 16 male and 16 female students in each experimental and control class. Based on their previous formative assessment scores, the students' average initial ability in both classes was in the moderate category, with ability levels (high, moderate, and low) relatively balanced across the two groups. All students had access to a mobile device (smartphone) or personal laptop and were familiar with using basic

digital learning applications. However, based on preliminary information from the teacher, the students had not previously experienced mathematics instruction that structured the integration of Desmos.

A total of 58 students (29 students per class) took the posttest and were included in the effectiveness analysis. Six students (three from each class) did not take the posttest.

The study site was selected because it suited the study's target population: eighth-grade junior high school students. The school implemented the national mathematics curriculum and provided an appropriate context for examining students' mathematical problem-solving ability at the junior high school level. In addition, the school was selected because it provided access to participants who met the study target and permitted the implementation of the planned instructional intervention.

The study was conducted in accordance with the ethical requirements of the UNY Ethics Committee. Participants were informed about the study's purpose and procedures and provided informed consent before data collection. Participation was voluntary, and participants could withdraw from the study without academic consequences.

Research Instrument

The research instrument consisted of a mathematical problem-solving ability test in the form of essay questions. The test consisted of five questions, each comprising three sub-questions that represented problem-solving indicators adapted from Polya's framework, namely: (1) understanding the problem by identifying the given information and what is being asked; (2) planning and implementing an appropriate solution strategy; and (3) evaluating the solution by checking the result and providing a brief justification. The distribution of test items based on the problem-solving indicators is presented in Table 1.

Table 1. Distribution of test items based on mathematical problem-solving indicators

Indicator	Pretest	Posttest	Number of Sub-items
Understanding the problem	1a, 2a, 3a, 4a, 5a	1a, 2a, 3a, 4a, 5a	5
Devising and carrying out appropriate strategies	1b, 2b, 3b, 4b, 5b	1b, 2b, 3b, 4b, 5b	5
Evaluating the solution/looking back	1c, 2c, 3c, 4c, 5c	1c, 2c, 3c, 4c, 5c	5

The instrument underwent content validation by two experts using the Aiken index. An Aiken's V value of 0.40 or less indicates low validity; a value between 0.40 and 0.80 indicates moderate validity; and a value greater than 0.80 indicates high validity (Retnawati, 2016). The validation results show that all test items have an Aiken's V index value of 0.875, thus meeting the validity criteria.

The reliability test using Cronbach's alpha yielded 0.697 for the pretest instrument and 0.675 for the posttest instrument. According to Ebel & Frisbie (1991), an instrument is considered reliable if the Cronbach's alpha value is greater than 0.65. Therefore, the instruments in this study are deemed reliable.

To ensure objectivity, we conducted an inter-rater reliability test using the Intraclass Correlation Coefficient (ICC) on a sample of students' responses. The analysis showed an ICC of 0.93 (95% CI: 0.76-0.98; $p < 0.001$). This result falls into the "very high" category, indicating that the Polya problem-solving rubric used demonstrates a very strong level of consistency and objectivity in scoring across raters.

Intervention Procedure

The study was conducted over six meetings. The first meeting was used to administer the mathematical problem-solving ability pretest to both classes. The following four meetings were used to implement the respective learning models in the experimental and control classes. The sixth meeting was used to administer the mathematical problem-solving ability posttest. All instructional

activities were conducted according to the schedule established by the school.

In the experimental class (VIII-F), the Guided Discovery Learning (GDL) model, supported by Desmos, was implemented during the second to fifth meetings. Each meeting lasted 80 minutes, consisting of 5 minutes for introductory activities, 70 minutes for core learning activities, and 5 minutes for closing activities. The instructional activities followed a sequence of cubes, cuboids, prisms, and pyramids. The GDL activities included problem identification, data collection and processing, verification, and generalization. Desmos was integrated into the learning activities to help students explore geometric concepts, including surface area and volume, through dynamic visualization and interactive representations. Students worked in groups using the provided worksheets while exploring geometric objects and their nets using Desmos. The activities were followed by verification through group discussions and presentations, teacher confirmation, and generalization of the mathematical concepts students discovered.

In the control class (VIII-G), the expository learning model was implemented during the second to fifth meetings using PowerPoint presentations. Each meeting also lasted 80 minutes and covered the same sequence of topics, namely cubes, cuboids, prisms, and pyramids. The teacher presented the concepts and formulas for surface area and volume, provided examples of non-routine problems with solution procedures, conducted question-and-answer sessions, and

assigned individual exercises to assess students' understanding.

Data Analysis

The analysis of learning effectiveness was based on posttest scores, in accordance with the study objectives. Learning effectiveness was determined based on the following criteria: (1) the average mathematical problem-solving ability reached the Learning Objective Achievement Criteria (KKTP) of 70; (2) the proportion of students who achieved the KKTP exceeded 75%; and (3) the learning outcomes of the experimental class were better than those of the control class.

Data analysis was conducted in stages. The effectiveness of learning in each class was analyzed based on three criteria. First, the average posttest score achievement relative to the KKTP of 70 was tested using a one-sample t-test. Second, learning mastery at the class level was tested using

a one-sample proportion test to determine whether the proportion of students who achieved the KKTP exceeded 75%. Third, the difference in mathematical problem-solving ability between the experimental and control classes was analyzed using a Type III Analysis of Covariance (ANCOVA) with pretest scores as the covariate and posttest scores as the dependent variable. Before conducting the ANCOVA, the assumptions of normality, homogeneity of variance, and homogeneity of regression slopes were tested first.

■ RESULT AND DISCUSSION

Descriptive Statistics and Initial Equivalence

Descriptive analysis was conducted to provide an overview of students' mathematical problem-solving ability before and after the treatment in both study groups. A description of the results is presented in Figure 1.

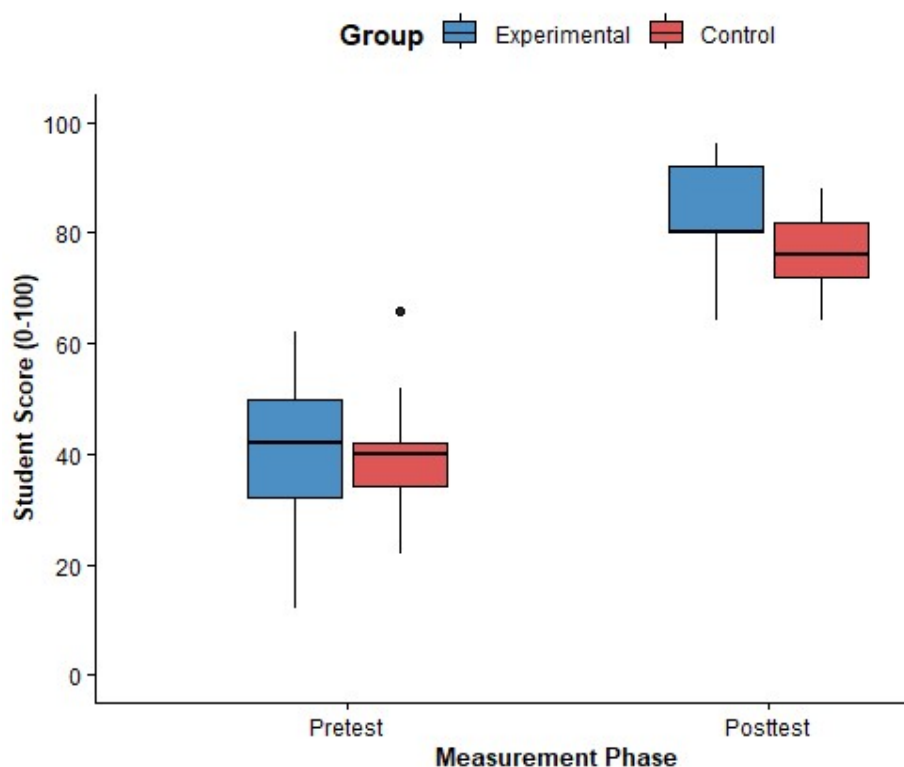


Figure 1. Descriptive statistics of students' mathematical problem-solving ability

Based on Figure 1, the distribution of pretest scores in the experimental and control classes appears relatively similar. After instruction, posttest scores in both groups increased compared with pretest scores, with the experimental class showing higher posttest scores than the control class. Next, to test the difference in mathematical problem-solving ability between

the two groups while controlling for students' initial ability, an Analysis of Covariance (ANCOVA) was conducted. Prior to the ANCOVA analysis, assumption tests were performed, including tests for normality, homogeneity of variance, and homogeneity of regression slopes. The results of the assumption tests are presented in Table 2.

Table 2. Results of assumption tests

Assumption	Group/Data	Method/Model	Statistic	p-value	Decision
Normality	Experimental	Shapiro-Wilk	0.945	0.135	Normal
	Control	Shapiro-Wilk	0.954	0.232	Normal
Homogeneity of Variance	Posttest	F-test	1.795	0.128	Homogeneous
Homogeneity of Regression Slopes	Pretest $\times$ Group	Interaction Model (F)	2.467	0.122	Homogeneous Slopes

Based on Table 2, all assumptions required for the ANCOVA analysis were met. The results indicate that the data meet the necessary conditions for estimating differences in posttest scores across groups while controlling for students' initial ability. Therefore, the analysis proceeded using a Type III ANCOVA with the pretest as a covariate.

Effectiveness of Guided Discovery Learning Assisted by Desmos

The effectiveness of the Guided Discovery Learning model, supported by the Desmos app,

in improving students' mathematical problem-solving skills was assessed using established effectiveness criteria. The evaluation included the average posttest score relative to the KKTP of 70, the proportion of students who achieved a KKTP score above 75%, and a comparison of mathematical problem-solving skills between the experimental and control classes after controlling for pretest covariates. The results of the effectiveness evaluation are presented in Table 3 and Table 4.

Based on Table 3, all predetermined effectiveness criteria were met. The mean

Table 3. Results of the effectiveness tests

Objective of the Test	Statistical Test	Test Statistic	df	p-value	95% CI Difference	Effect Size	Decision
Mean score exceeded the KKTP	One-sample t-test	8.01	28	5.02×10^{-9}	[9.55, 16.11]	1.49 (d)	Reject H_0
Classical learning mastery exceeded 75%	One-Sample Z-Test	2.265	-	0.012	-	-	Reject H_0

Table 4. Summary of ANCOVA and adjusted means for problem-solving ability

Source of Variation / Group	Sum of Squares	df	Mean Square	F	p-value	η_p^2	Adjusted Mean	Standard Error
Pretest (Covariate)	196.6	1	196.6	3.547	0.065	0.08	-	-
Group (Treatment)	481.3	1	481.3	8.684	0.005	0.14	-	-

Error (Residuals)	3048.4	55	55.425	-	-	-	-	-
Experimental Class	-	-	-	-	-	-	82.60	1.39
Control Class	-	-	-	-	-	-	76.80	1.39

mathematical problem-solving ability of students in the experimental class significantly exceeded the KKTP of 70. In addition, the proportion of students who achieved the KKTP exceeded 75%.

To objectively evaluate differences between groups without being influenced by variations in initial ability, a Type III ANCOVA analysis was conducted. The ANCOVA results in Table 4 show a significant difference in mathematical problem-solving ability between students in the experimental and control classes after controlling for pretest scores. The adjusted mean scores in the experimental class were significantly higher than those in the control class. Furthermore, the magnitude of the intervention effect, as indicated by the partial eta-squared value, fell into the “large effect size” category, suggesting that 14% of the

variance in students’ mathematical problem-solving skills was attributable to implementing the Desmos-assisted Guided Discovery Learning model after accounting for the pretest covariate. Thus, the Desmos-assisted Guided Discovery Learning model proved effective and significantly superior to the expository model in improving students’ mathematical problem-solving skills.

The comparison between the experimental and control classes also showed that students in the experimental class had significantly higher mean mathematical problem-solving ability than those in the control class. Thus, Guided Discovery Learning assisted by the Desmos application effectively improved students’ mathematical problem-solving ability. The class-level mastery is presented in detail in Figure 2.

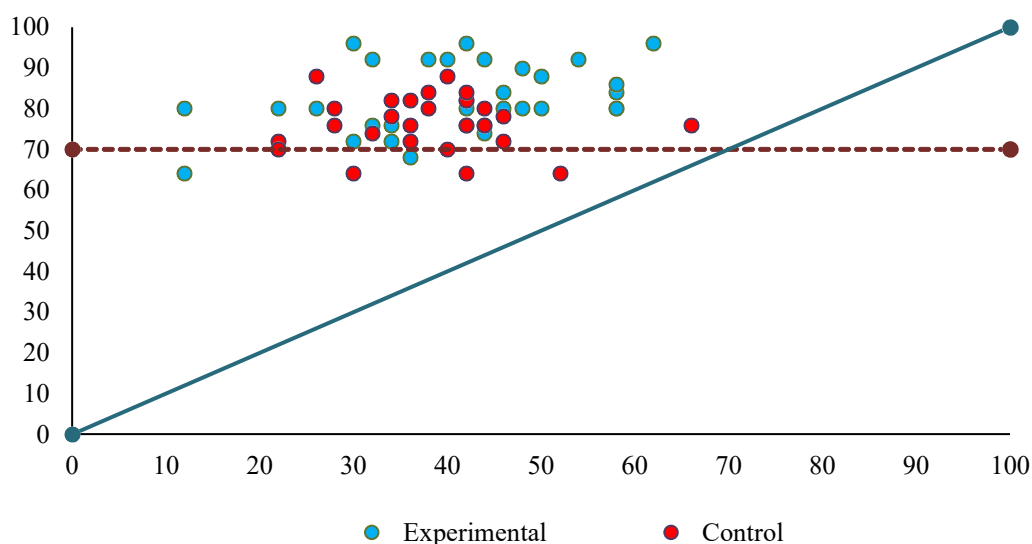


Figure 2. Distribution of students’ pretest and posttest scores in the experimental and control groups

The distribution of pretest and posttest scores in Figure 2 shows improved mathematical problem-solving ability in both groups. However, the improvement in the experimental class appears

to be greater, with most posttest scores falling within the range of 80–96. In addition, almost all students in the experimental class achieved the KKTP of 70. This finding indicates that

independent discovery contributed to more optimal achievement in problem solving. This aligns with the view that learning environments that support active exploration and independent knowledge construction can strengthen students' metacognitive structures when dealing with non-routine mathematical problems (Lee et al., 2014).

The difference in achievement between the experimental and control classes can be understood from the characteristics of GDL, which positions students as active participants in constructing knowledge through a guided discovery process. In this study, the concept-discovery process began with problem identification by presenting a visual cognitive conflict through Desmos. Students were not directly given procedures or formulas for solving the problems but were guided to formulate and communicate their initial hypotheses using the multiple-choice and answer box features. This activity provided students with opportunities to identify the problems and propose conjectures based on the information they observed.

Next, during the data collection phase, students answered the questions provided in Desmos using the table and Polypad features. Using these two features helped students gather the necessary information while identifying and applying problem-solving strategies. The exploration continued into the data processing phase, using the Polypad, slider, and split features in Desmos to explore the shapes of three-dimensional figures and discover patterns in the relationships between flat sides, surface area, and volume. Direct visualization and manipulation of objects allowed students to observe changes and relationships between components more concretely. These exploratory activities influence students' motivation to learn (Koller, 2024), and integrating technology with structured exploratory tasks fosters deep conceptual understanding (Mavrikis et al., 2022). Consequently, exploratory activities can support students' ability

to select and implement problem-solving strategies when facing mathematical problems.

In the tentative conclusion phase, students used Desmos's open-ended/free-response feature to write down their reasoning and justifications for their findings. These responses could then be discussed collectively, allowing the teacher to clarify errors in students' conceptual thinking. Subsequently, the verification phase was conducted using the check box and card sort features to examine the consistency of students' findings. These verification activities provide students with an opportunity to reevaluate their results before applying them in broader contexts. Verification activities in problem-solving tasks serve as an effective metacognitive monitor (Janssen & Lazonder, 2024). Furthermore, this evaluation process fosters students' cognitive flexibility in applying concepts to new situations and challenges.

In the generalization phase, students used Desmos's answer box feature to apply their findings to solve mathematical problems. Thus, the knowledge gained through the exploration process did not stop at discovering a pattern or relationship but was further applied to problem-solving situations. This sequence of activities shows that GDL assisted by Desmos provides a learning experience that integrates understanding problems, determining and implementing solution strategies, and evaluating solutions. This finding reinforces international and national empirical research confirming that implementing Guided Discovery Learning consistently has a significant positive effect on students' mathematical problem-solving and reasoning abilities at the secondary school level (Agus, 2019; Kokeb et al., 2025). Desmos can also support mathematics learning by providing visual representations and an interactive environment for exploration (Ferianto et al., 2023). Furthermore, these findings support the view that technology-integrated learning has a promising impact on education (Kalita & Nath, 2025).

The overall difference in achievement between the experimental and control classes can be further examined by the indicator of mathematical problem-solving ability. Figure 3 presents the mean pretest and posttest scores for each indicator in the two groups.

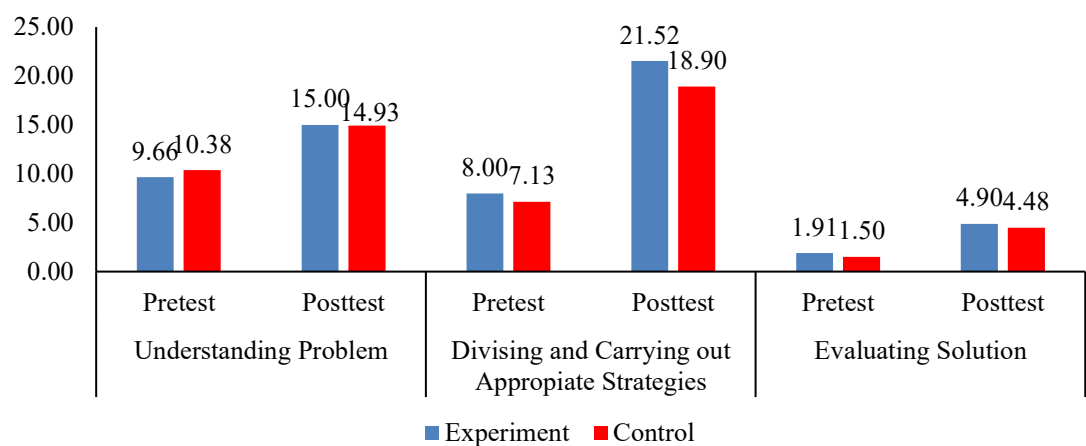


Figure 3. Mean score of mathematical problem-solving ability

Based on Figure 3, implementing the Guided Discovery Learning model assisted by Desmos positively affected students’ mathematical problem-solving ability across all three measured indicators. For the *understanding problem* indicator, with a maximum score of 15, the experimental group had a mean pretest score of 9.66, slightly lower than the control group’s 10.38. However, after the treatment, the experimental group increased by 5.34 points, reaching a posttest score of 15, the maximum score achievable on this indicator. This score exceeded that of the control group, which increased by 4.55 points to a final score of 14.93. The greater improvement in the experimental group indicates that graph manipulation and dynamic visualization in Desmos helped students identify information and formulate mathematical problems more effectively. This finding is consistent with Mabhoza & Olawale (2024), who stated that Guided Discovery Learning helps students understand mathematical problems.

A similar positive trend was observed for the *devising and carrying out appropriate strategies* indicator, with a maximum score of 30. The experimental group obtained a pretest

score of 8 and increased to 21.52 on the posttest, representing an improvement of 13.52 points. This result was higher than that of the control group, which increased from 7.13 to 18.90, an improvement of 11.77 points. This advantage suggests that independent discovery through exploration with Desmos helped students identify solution paths and perform mathematical calculations more accurately. This finding is also consistent with the results of Kokeb et al. (2025), Nurhayani et al. (2020), and Simamora et al. (2018), who reported that Guided Discovery Learning can improve students’ ability to determine and implement problem-solving strategies.

For the *evaluating solution* indicator, both groups began with relatively low scores, namely 1.91 for the experimental group and 1.50 for the control group. Following the instruction, the experimental group achieved a posttest score of 4.90, representing an increase of 2.99 points, while the control group achieved a score of 4.48, representing an increase of 2.98 points. Overall, these results confirm that integrating Desmos with the Guided Discovery Learning model consistently supported students’ achievement and

improvement in mean scores across all stages of mathematical problem solving compared with the control instruction. Overall, the data indicate that the experimental group improved in mathematical problem-solving ability more than the control group.

The effectiveness of Guided Discovery Learning assisted by Desmos depends not only on the process of discovering and verifying concepts but also on the generalization phase. At this stage, students, with the teacher, draw conclusions about the surface area and volume formulas they discovered and then apply them to solve non-routine problems presented through the Desmos application. This activity gives students opportunities to apply the concepts they have constructed to different situations, so their understanding does not stop at mastering formulas but develops into the ability to apply concepts flexibly in solving mathematical problems. Thus, each phase of Guided Discovery Learning complements the others in developing conceptual understanding while simultaneously training students to apply concepts in mathematical problem solving.

Overall, students who participated in Guided Discovery Learning demonstrated better mathematical problem-solving ability across all indicators than students in the expository class. This advantage can be attributed to GDL's characteristics, which actively engage students in constructing knowledge through problem identification, data collection, data processing, tentative conclusion, verification, and generalization. This sequence of activities gives students opportunities to explore information, build conceptual understanding, and develop and evaluate problem-solving strategies. This finding is consistent with Kokeb et al. (2025), who showed that guided discovery was superior to conventional learning in improving students' mathematical problem-solving ability. The finding also supports Agus (2019), which showed that

stages in GDL, such as problem identification, *experiencing*, and drawing conclusions, provide students with opportunities to explore and construct knowledge independently. Thus, students' active engagement throughout the discovery process can support the development of mathematical problem-solving ability.

■ CONCLUSION

The Guided Discovery Learning (GDL) model, supported by the Desmos application, was more effective than the expository learning model in terms of students' mathematical problem-solving ability. The GDL model supported by Desmos not only helped students develop a deeper understanding of mathematical concepts but also encouraged them to actively explore, analyze relationships among the facts they encountered, and evaluate their findings, thereby supporting the development of their mathematical problem-solving ability. The findings indicate that student-centered learning supported by interactive digital technology can produce better outcomes than conventional learning.

In implementation, teachers are encouraged to use the Guided Discovery Learning model, supported by Desmos, as an alternative instructional approach that facilitates students' active exploration and the development of mathematical problem-solving ability. However, technology use should be paired with an alternative instructional scenario to anticipate technical disruptions in the classroom. Teachers need to prepare non-digital activities or media that maintain the learning objectives and cognitive flow of the instruction, such as printed images or nets of three-dimensional shapes, exploration worksheets, concrete manipulatives, or guiding questions equivalent to the visual activities provided through Desmos. Thus, when the application or device malfunctions, teachers can systematically shift the activity from technology-based exploration to visual representations or

concrete manipulatives without interrupting students' process of discovering concepts and solving mathematical problems.

Teachers are encouraged to implement the Guided Discovery Learning model, supported by the Desmos application, as an alternative instructional approach that can facilitate students' active exploration and improve their mathematical problem-solving ability. Future research could examine the effectiveness of this learning model across different mathematical topics, educational levels, and mathematical abilities, and investigate students' problem-solving processes in greater depth using qualitative or mixed-methods approaches.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the authors employed DeepL and ChatGPT to assist with language refinement/proofreading. The authors reviewed and edited the content generated by these tools and assume full responsibility for the content of the published article.

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