



THE EFFECT OF IMPLEMENTING THE DISCOVERY LEARNING MODEL ASSISTED BY GEOGEBRA ON THE MATHEMATICAL CONCEPTUAL UNDERSTANDING OF GRADE IX STUDENTS AT SMPN 24 PADANG

Ghina Luthfia Alfarisa^{1*}, Yerizon², Armianti³, Yarman⁴

^{1,2,3,4} Mathematics Education Study Program, Padang State University, Indonesia

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ABSTRACT

Mathematical concept understanding is one of the fundamental competencies students must master in learning mathematics, particularly as a foundation for developing other mathematical abilities such as problem solving, reasoning, and communication. However, the mathematical concept understanding of ninth-grade students at SMPN 24 Padang has not yet reached an optimal level, particularly on the topic of geometric transformation, which requires accuracy in understanding visual representation and spatial relationships. This study aimed to determine whether the mathematical concept understanding of students who learned using the Discovery Learning model assisted by GeoGebra was better than that of students who learned through the conventional model. This study was a quasi-experimental study employing a Nonequivalent Posttest-Only Control Group Design. The population consisted of ninth-grade students of SMPN 24 Padang in the 2026/2027 academic year, with class IX.A as the experimental class and class IX.E as the control class, selected through simple random sampling. Data were collected through a final test of mathematical concept understanding covering eight indicators and analyzed using the Mann-Whitney test. The results showed that the average score of the experimental class (82.14) was higher than that of the control class (70.87), with a P-value of $0.001 < 0.05$. Therefore, the Discovery Learning model assisted by GeoGebra had a positive effect on students' mathematical concept understanding.

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* Corresponding author: luthfiaalfarisa@gmail.com

INTRODUCTION

Mathematics plays an important role in education because it serves as a fundamental discipline that supports various other fields of knowledge and is closely related to concrete situations encountered in everyday life. As a fundamental discipline, mathematics underpins other fields, such as physics, chemistry, and computer science (Julyanti et al., 2021). In everyday life, mathematics is also closely related to various practical problems encountered by students (Damarasri et al., 2024). Therefore, one of the important learning outcomes to be developed in mathematics education is mathematical conceptual understanding. This is a fundamental ability that students must acquire before learning subsequent material, as it serves as the foundation for other mathematical competencies, including problem-solving, reasoning, and mathematical communication (Nurfadila et al., 2022). According to the Regulation of the Minister of Education and Culture of the Republic of Indonesia No. 58 of 2014, mathematical conceptual understanding is a competency that demonstrates the ability to understand relationships between concepts and algorithms flexibly, accurately, efficiently, and appropriately when solving problems. This perspective is consistent with the National Council of Teachers of Mathematics (2000), which emphasizes that students should learn mathematics with understanding by actively constructing new knowledge based on their prior experiences and knowledge.

Students' mathematical conceptual understanding can be assessed through eight interrelated indicators. These indicators, as formulated in the Regulation of the Minister of Education and Culture of the Republic of Indonesia No. 58 of 2014, include restating concepts, classifying objects based on concepts, identifying the properties of operations or concepts, applying concepts logically, providing examples and non-examples, representing concepts in various mathematical forms, relating mathematical concepts to one another and to concepts outside mathematics, and developing the necessary and sufficient conditions for a concept. Students can be considered to have good mathematical conceptual understanding when they are able to demonstrate mastery of all eight indicators. However, evidence from educational settings indicates that students' mathematical conceptual understanding remains relatively low across various educational levels.

This condition is demonstrated by Afifah et al. (2024), who found that the mathematical conceptual understanding of senior high school students in Bandung was not yet optimal. Similar findings were reported by Boas et al. (2025) among junior high school students in Padang, while Verina and Darhim (2023) revealed that junior

high school students had not yet developed a satisfactory understanding of mathematical concepts. Similar findings were reported by Lenamah et al. (2022), who analyzed the mathematical conceptual understanding of 17 seventh-grade students at SMP Negeri Siso. Their findings showed that only four students (23.52%) were in the high category and met all indicators, whereas ten students (58.82%) were in the moderate category and three students (17.64%) were in the low category. Septiani and Aini (2023) also found that the mathematical conceptual understanding of eighth-grade students at SMP Al-Mushlih Karawang regarding triangles and quadrilaterals was low, with a mean score of 48.93 and only 42.78% of students demonstrating conceptual understanding. This condition was partly attributed to the inappropriate use of instructional methods.

Low mathematical conceptual understanding was also observed among ninth-grade students at SMPN 24 Padang. Based on observations conducted during the Educational Field Practice (*Praktik Lapangan Kependidikan* or PLK), mathematics instruction at the school was still predominantly teacher-directed, resulting in students tending to be passive and less actively involved in discovering mathematical concepts. The results of an initial test of mathematical conceptual understanding on exponents and radicals further supported this finding, with representing concepts in various mathematical forms emerging as the indicator with the greatest difficulty. One approach to addressing this issue is to implement an instructional model that encourages students to actively discover concepts, such as the *Discovery Learning* model. Anggraeni et al. (2020) demonstrated that implementing *Discovery Learning* can improve students' mathematical conceptual understanding because the model encourages them to discover concepts independently through six learning stages: stimulation, problem statement, data collection, data processing, verification, and generalization (Sinambela, 2017).

The *Discovery Learning* model offers several advantages relevant to improving mathematical conceptual understanding. According to Khasinah (2021), this model actively engages students in the learning process, encourages independent learning, builds upon students' prior knowledge and experiences, helps them retain concepts they discover themselves, and facilitates collaborative learning. Mafrudah and Edy (2023) stated that this model encourages intuitive thinking and hypothesis formulation, develops independent learning skills, and improves problem-solving abilities, as demonstrated in a classroom action research study involving seventh-grade students at SMPN 1 Taman. Furthermore, Dwi Darmawan et al. (2025), in a study involving ninth-grade students at SMP Negeri 13 Mataram, found that implementing *Discovery Learning* on exponents and radicals increased the mean

conceptual understanding score from 60.00 in the pre-cycle to 75.50 in Cycle I and 85.75 in Cycle II. The proportion of students achieving the mastery criterion also increased from 35% to 85%. These findings suggest that *Discovery Learning* has the potential to strengthen conceptual understanding through active engagement and independent concept discovery.

Although the *Discovery Learning* model has been shown to be effective, its implementation may have limitations when the learning material requires precision in understanding visual representations and spatial relationships, as in geometric transformations, which include translation, reflection, rotation, and dilation. In this topic, students often experience difficulties understanding changes in the position and shape of objects and relating coordinate changes to the resulting transformations on the Cartesian plane. These difficulties may hinder the concept discovery process when it is not supported by media capable of dynamically visualizing geometric transformations. One medium that can address these limitations is *GeoGebra*, dynamic software that visualizes mathematical concepts through the integration of geometry, algebra, and graphics (Hohenwarter & Fuchs, 2004; Mahmudi, 2010). Hermawan et al. (2023) found that the improvement in mathematical conceptual understanding among students taught using the *Discovery Learning* model assisted by *GeoGebra* was greater than that among students taught using conventional instruction.

Based on the foregoing discussion, this study aims to investigate the effect of implementing the *Discovery Learning* model assisted by *GeoGebra* on the mathematical conceptual understanding of ninth-grade students at SMPN 24 Padang. The effect is examined specifically through students' post-test results on mathematical conceptual understanding in geometric transformations by comparing the achievement of students in the experimental class, which received instruction using the *Discovery Learning* model assisted by *GeoGebra*, with that of students in the control class, which received conventional instruction. The findings are expected to provide empirical evidence regarding the effectiveness of the *Discovery Learning* model assisted by *GeoGebra* in improving students' mathematical conceptual understanding, particularly in topics that require visual representation and spatial reasoning. Furthermore, the findings are expected to offer mathematics teachers an alternative instructional strategy for improving mathematical conceptual understanding among junior high school students.

METHOD

The research employed a quasi-experimental method. This study aimed to determine whether the mathematical conceptual understanding of students taught using the *Discovery Learning* model assisted by *GeoGebra* was better than that of students taught using conventional instruction, considering that not all external variables affecting the research implementation could be fully controlled. The research design used was the *Nonequivalent Posttest-Only Control Group Design* (Lestari & Yudhanegara, 2015), as presented in Table 1.

Table 1. Nonequivalent Posttest-Only Control Group Design

Class	Experiment	Posttest
Experimental	X	O
Control	-	O

Note :

X = Instruction using the *Discovery Learning* model assisted by *GeoGebra*

- = Conventional instruction

O = Posttest of mathematical conceptual understanding

The research design was applied to a population comprising all ninth-grade students at SMPN 24 Padang in the 2026/2027 academic year. Before selecting the sample classes, a test of mean equality was conducted using end-of-semester assessment scores. The analyses included a normality test, a homogeneity test, and a one-way ANOVA to determine whether the population data were normally distributed, homogeneous, and had equal means, ensuring that any selected class could fairly represent the population. After these assumptions were satisfied, the sample was selected using the *Simple Random Sampling* technique through a lottery method. Class IX.A, was selected as the experimental class and received instruction using the *Discovery Learning* model assisted by *GeoGebra*. Class IX.E, was selected as the control class and received conventional instruction (direct instruction).

In both sample classes, instruction on geometric transformations was conducted over six sessions, followed by one session for the mathematical conceptual understanding posttest. Mathematical conceptual understanding of geometric transformations was measured using a posttest consisting of eight essay questions developed based on the eight indicators of mathematical conceptual understanding specified in Regulation of the Minister of Education and Culture No. 58 of 2014. The instrument was validated by two lecturers from the Department of Mathematics at Universitas Negeri Padang and subsequently piloted at SMPN 11 Padang to determine item discrimination, item difficulty, and reliability before being administered to the sample classes. The posttest was scored using an analytical scoring

rubric adapted from Iryanti (2004), enabling the identification of students' strengths and weaknesses across each indicator of mathematical conceptual understanding. The posttest was administered to both sample classes after all six instructional sessions had been completed.

After the posttest data were collected from both sample classes, the data were analyzed using the Anderson–Darling normality test to determine whether they were normally distributed. If the data were normally distributed, the parametric *t*-test was applied. Otherwise, the nonparametric Mann–Whitney test was used. All data analyses were performed using Minitab software at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The posttest of mathematical conceptual understanding was administered at the end of the study to compare the mathematical conceptual understanding of students in the experimental class, which received instruction using the *Discovery Learning* model assisted by *GeoGebra*, with that of students in the control class, which received conventional instruction. The posttest results are presented in Table 2.

Table 2. Posttest Results of Students' Mathematical Conceptual Understanding in the Sample Classes

Class	Number of Students	Mean Score	Standard Deviation	Highest Score	Lowest Score
Experimental	31	82.14	9.539	96.43	53.57
Control	32	70.87	12.44	85.71	32.14

As shown in Table 2, the experimental class obtained a higher mean posttest score for mathematical conceptual understanding (82.14) than the control class (70.87). The highest score in the experimental class (96.43) was also higher than that in the control class (85.71). Similarly, the lowest score in the experimental class (53.57) exceeded that in the control class (32.14). The standard deviation in the experimental class (9.539) was lower than that in the control class (12.44), indicating that the scores in the experimental class were less dispersed than those in the control class. These findings suggest that implementing the *Discovery Learning* model assisted by *GeoGebra* was associated not only with a higher mean level of mathematical conceptual understanding but also with more consistent student achievement.

Students' mathematical conceptual understanding in both sample classes can also be examined through the mean scores for each indicator, as presented in Table 3.

Table 3. Comparison of Mean Scores for Each Indicator of Mathematical Conceptual Understanding in the Sample Classes

No	Indicator of Mathematical Conceptual Understanding	Maximum Score	Experimental Class	Control Class
1	Restating a concept	2	1.90	1.97
2	Classifying objects according to whether they satisfy the requirements defining a concepts	4	2.94	2.91
3	Identifying the properties of operations or concepts	4	3.03	1.63
4	Applying concepts logically	4	3.06	2.84
5	Providing examples or non-examples of a learned concept	2	1.84	1.63
6	Representing concepts in various mathematical forms	4	3.77	3.44
7	Connecting mathematical concepts with one another and with concepts outside mathematics	4	2.90	2.53
8	Developing the necessary and sufficient conditions for a concept	4	3.55	2.91

The differences in achievement presented in Table 3 can be interpreted in relation to the six stages of the *Discovery Learning* model: stimulation, problem statement, data collection, data processing, verification, and generalization. Each stage is designed to develop one or more indicators of mathematical conceptual understanding. By examining these six stages in sequence, it is possible to explain why the experimental class achieved higher mean scores than the control class on most indicators.

The first stage, *stimulation*, is associated with the indicator of restating a concept because contextual stimuli presented at the beginning of a lesson encourage students to recall and restate previously learned concepts. At this stage, the experimental class obtained a mean score of 1.90, which was relatively comparable to the control class score of 1.97, because both classes began with an introductory review before proceeding to the main material. More noticeable differences between the two classes emerged in subsequent stages that required more complex thinking processes.

Following *stimulation*, the learning process proceeded to the *problem statement* stage, which is related to the indicator of identifying the properties of operations or concepts. At this stage, students were guided to identify and formulate problems as hypotheses through exploration using *GeoGebra*. This process encouraged them to

relate their answers to the properties of geometric transformations that they discovered independently. Consequently, the experimental class obtained a mean score of 3.03 for this indicator, substantially higher than the control class score of 1.63. In contrast, students in the control class tended to write formulas without relating them to the specific properties of the transformations being examined, as they had primarily learned the concepts through teacher explanations.

The hypotheses formulated during the *problem statement* stage were subsequently tested during the *data collection* stage, which is associated with two indicators: applying concepts logically and developing the necessary and sufficient conditions for a concept. At this stage, students collected information through *GeoGebra* exploration and student worksheets (*Lembar Kerja Peserta Didik*, or LKPD) to test their hypotheses and independently formulate the conditions governing geometric transformations. The experimental class obtained a mean score of 3.06 for applying concepts logically, compared with 2.84 in the control class. For developing the necessary and sufficient conditions for a concept, the experimental class achieved a mean score of 3.55, compared with 2.91 in the control class. This independent exploration process provided students in the experimental class with more opportunities to apply concepts systematically and formulate the conditions of transformations more comprehensively than students in the control class, who primarily learned concepts through examples demonstrated by the teacher.

The data and information collected in the previous stage were then processed during the *data processing* stage, which is related to the indicator of classifying objects according to whether they satisfy the requirements defining a concept. At this stage, students processed and classified the data obtained through exploration to identify patterns and discover transformation concepts. The experimental class achieved a mean score of 2.94, only slightly higher than the control class score of 2.91. The similarity between these scores suggests that both classes demonstrated relatively comparable abilities to classify objects, although students in the experimental class engaged more directly in independently discovering patterns.

The patterns and concepts identified during *data processing* were subsequently examined during the *verification* stage. This stage is associated with two indicators: providing examples or non-examples of learned concepts and representing concepts in various mathematical forms. Students verified and reviewed their findings through presentations and further explanations from the teacher. The experimental class obtained a mean score of 1.84 for providing examples or non-examples, compared with 1.63 in the control class. For mathematical representation, the experimental class achieved a mean score of 3.77, whereas the control class obtained

3.44. Although the experimental class achieved a higher score for mathematical representation, some students in both classes did not fully represent the original points and their images after transformation on the Cartesian coordinate plane.

The sequence of *Discovery Learning* stages concluded with *generalization*, which is associated with the indicator of connecting mathematical concepts with one another and with concepts outside mathematics. At this stage, students drew general conclusions based on the verification conducted in the preceding stage. The experimental class obtained a mean score of 2.90, exceeding the control class score of 2.53. Regularly drawing their own conclusions from exploration activities during each lesson provided students in the experimental class with more opportunities to connect transformation concepts with real-world contexts and other mathematical concepts. In contrast, students in the control class were more accustomed to receiving conclusions directly from the teacher.

Overall, the relationship between the six stages of the *Discovery Learning* model assisted by *GeoGebra* and the eight indicators of mathematical conceptual understanding suggests that the higher achievement observed in the experimental class was associated with a learning process that encouraged students to discover, verify, and formulate conclusions independently at each stage. In this process, *GeoGebra* helped visualize abstract geometric transformations, making them more concrete and facilitating students' understanding of spatial relationships and coordinate changes across different types of transformations (Mahmudi, 2010; Suciati & Mailili, 2022).

To determine whether the differences in achievement between the two classes were statistically significant rather than attributable to chance, a hypothesis test was conducted using the posttest data. Before testing the hypothesis, the normality of the data was examined using the Anderson–Darling test. The results indicated a p -value of 0.142 for the experimental class ($p > 0.05$), suggesting that the data were normally distributed, whereas the control class had a p -value of less than 0.005, indicating that the data were not normally distributed. Because the data from one class did not follow a normal distribution, the nonparametric Mann–Whitney test was subsequently used to test the hypothesis. Because this test compares the distributions of two independent samples rather than their means, the statistical hypotheses were formulated in terms of the population medians (η), stated as $H_0: \eta_1 = \eta_2$ and $H_1: \eta_1 > \eta_2$, where η_1 and η_2 denote the median posttest scores of the experimental and control classes, respectively. The test assumes that the two samples are independent, conditions that are satisfied here because the two classes are separate groups and the posttest scores are numerical. Interpreting the result as a difference in medians

additionally presumes that the two score distributions have a broadly similar shape, which should be kept in mind because the control-class distribution departed from normality.

The median score of the experimental class (82.14) was higher than that of the control class (75.00), with an estimated difference of 10.71. The hypothesis test, conducted using Minitab software with a one-sided alternative, yielded a p -value of 0.000 ($p < 0.001$). Since the p -value was below the significance level of $\alpha = 0.05$, H_0 was rejected in favor of H_1 . Therefore, it can be concluded that students taught using the *Discovery Learning* model assisted by *GeoGebra* demonstrated better mathematical conceptual understanding than students taught using conventional instruction in Grade IX at SMPN 24 Padang.

The hypothesis-testing results further support the achievement patterns discussed for the individual indicators. These findings are consistent with Hermawan et al. (2023), who reported that improvements in mathematical conceptual understanding were greater among students taught using the *Discovery Learning* model assisted by *GeoGebra* than among those receiving conventional instruction. The findings also align with Astrilia et al. (2025), who stated that *GeoGebra* provides students with opportunities to visualize problems, thereby supporting the discovery of mathematical concepts.

This pattern was also observed during the learning process: students in the experimental class worked collaboratively using student worksheets assisted by *GeoGebra*, demonstrating greater enthusiasm and actively asking the teacher questions about using the software and interpreting the problems provided. Conversely, students in the control class, which employed direct instruction, tended to listen to explanations and follow examples demonstrated by the teacher. As a result, they were more passive and dependent on the teacher throughout the learning process. This observation is consistent with Islamiyah et al. (2025), who found that monotonous direct instruction tends to make students passive. These differences in classroom engagement may help explain why the mathematical conceptual understanding of students in the control class was lower than that of students in the experimental class.

The implementation of the *Discovery Learning* model assisted by *GeoGebra* in the experimental class was not without challenges. The first challenge was the limited time available to complete the activities in the student worksheets. Because students were unfamiliar with the stages of *Discovery Learning*, they needed time to adjust and frequently asked the teacher for clarification when they encountered difficulties. Consequently, group presentations could not always be conducted comprehensively

during every lesson. The second challenge was the limited availability of devices for operating *GeoGebra*. Since students were not permitted to bring smartphones to school, they could not independently operate the software on their own devices. To address this limitation, the researcher used a smartboard, which each group took turns using during the lessons. The third challenge involved some students' reluctance to accept their assigned groups because their group members did not match their preferences. The researcher therefore explained that group assignments were made fairly, taking into account each student's ability level. These three challenges provide important considerations for the implementation of the *Discovery Learning* model assisted by *GeoGebra* in future studies, as discussed further in the recommendations section.

CONCLUSION

Based on the results and discussion presented, the posttest results and hypothesis testing conducted in Classes IX.A and IX.E at SMPN 24 Padang in the 2026/2027 academic year indicate that students taught using the *Discovery Learning* model assisted by *GeoGebra* demonstrated better mathematical conceptual understanding than those taught using conventional instruction. This finding is supported by the higher mean posttest score in the experimental class (82.14) compared with the control class (70.87), as well as the Mann–Whitney test result ($p < 0.001$). Therefore, the *Discovery Learning* model assisted by *GeoGebra* has a positive effect on the mathematical conceptual understanding of ninth-grade students at SMPN 24 Padang in the 2026/2027 academic year.

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