Kognitif
Jurnal Riset HOTS Pendidikan Matematika
Volume - 6 No - 3 2026 Page 1376 – 1395
ISSN 2776-9704 P-ISSN 2776-9984
https://doi.org/10.51574/kognitif.v6i3.5373

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How to cite: Lestari, R., Heryani, Y., & Natalliasari, I. (2026). Effect of GeoGebra-Assisted Discovery Learning on Junior High School Students' Conceptual Understanding of Straight-Line Equations. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *6*(3), 1376–1395. https://doi.org/10.51574/kognitif.v6i3.5373

To link to this artcle: https://doi.org/10.51574/kognitif.v6i3.5373

Opened Access Article

Published Online on 09 September 2026

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https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

Effect of GeoGebra-Assisted Discovery Learning on Junior High School Students' Conceptual Understanding of Straight-Line Equations

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Article Info

Article history:

Received Jun 22, 2026
Accepted Sep 03, 2026
Published Online Sep 09, 2026

Keywords:

Discovery Learning
GeoGebra
Understanding of Mathematical Concepts

ABSTRACT

Developing conceptual understanding remains a central challenge in mathematics education, particularly when students rely on procedural formulas without understanding the relationships among mathematical representations. This study examined whether GeoGebra-assisted discovery learning was associated with higher conceptual understanding of straight-line equations among eighth-grade students. A quasi-experimental posttest-only control-group design was employed involving 60 students from SMP Negeri 14 Tasikmalaya, Indonesia, assigned to an experimental class 30 students and a control class 30 students. The experimental group received GeoGebra-assisted discovery learning, whereas the control group received without GeoGebra-assisted discovery learning. Students' conceptual understanding was assessed using a validated 5-item open-ended test. Data were analyzed using descriptive statistics and an independent-samples t-test, complemented by Cohen's d to estimate the magnitude of the between-group difference. The experimental group obtained a higher mean posttest score ($M = 11.10$) than the control group ($M = 8.47$), and the difference was statistically significant ($p = .003$). The standardized mean difference was $d = 0.79$, indicating a substantial advantage for students who participated in GeoGebra-assisted discovery learning. Within the experimental group, 16.67% of students were classified as having high conceptual understanding, 70.00% moderate understanding, and 13.33% low understanding. These findings suggest that integrating dynamic GeoGebra representations into discovery-oriented activities can support students' conceptual understanding of straight-line equations. The study provides empirical evidence for the instructional value of combining guided mathematical discovery with dynamic representations in junior high school mathematics.

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Introduction

Mathematical concept understanding is a student's ability to grasp, organize, and understand mathematical ideas systematically (Nurani et al., 2021). According to Yolanda (2020), understanding of a concept is demonstrated through a person's ability to rephrase that concept in their own words clearly and in detail. Therefore, students with a strong understanding of mathematical concepts tend to be better able to apply the concepts they have learned both in everyday contexts and in solving various mathematical problems (Meidianti et al., 2022). Hus, the understanding of mathematical concepts plays a crucial role in learning, as it serves as the foundation for students to build knowledge and develop mathematical problem-solving skills.

Nevertheless, students' ability to understand mathematical concepts remains an issue that requires attention. Aulia & Abadi (2024), reported that in an algebra course at a junior high school in Bekasi, 51.7% of students fell into the low category in terms of mathematical conceptual understanding, while only 10.3% reached the high category. These findings align with the results of interviews conducted with mathematics teachers at SMP Negeri 14 Tasikmalaya, which indicated that some students still struggle to understand mathematical concepts, particularly when translating contextual problems into more abstract mathematical models. Furthermore, students tend to rely on textbook-oriented learning without deeply understanding the meaning of concepts, and they are not yet accustomed to applying the concepts they have learned to various different situations. This situation aligns with the findings of a study by Agustini & Pujiastuti (2017), which revealed that students struggle to solve word problems because they are unable to understand the information provided, represent it using mathematical symbols, and connect the necessary concepts to arrive at the correct solution.

One of the mathematics topics that students still find difficult is straight line equations, particularly for junior high school students. This material is considered challenging because it requires an integrated understanding of concepts, representations, and procedures. Common difficulties include students' inability to connect the concept of slope with the form of a straight line equation, challenges in interpreting graphs, and an inability to accurately link various representations (verbal, symbolic, and graphical). Consequently, a similar situation was observed at SMP Negeri 14 Tasikmalaya, where it was found that students' level of understanding of mathematical concepts during the learning process remained low, only about 20% of students demonstrated optimal conceptual understanding. These findings align with the results of a study conducted by Manihuruk et al., (2024), which found that no students met the minimum competency standard (KKM) and that the majority of students struggled to express concepts through various forms of representation. Similar results were reported by Nugroho & Sutirna (2023), who showed that students still struggled to understand the meaning of equations and the relationship between graphs and equations. These findings are reinforced by research conducted by Lenamah et al., (2022), which showed that the majority of students at Siso Public Junior High School still fall into the moderate to low categories in terms of mathematical conceptual understanding, meaning that only a few students are truly able to reach the high category.

The low level of mathematical conceptual understanding observed in the field indicates that this ability remains a serious challenge that requires attention. These findings align with the results of a preliminary study conducted by Darwani et al., (2023) on 23 seventh-grade students in Class VII-5 at MTsN 2 Aceh Besar, where the achievement rate was only 24.72%. This situation demonstrates that junior high school students' understanding of mathematical concepts is still suboptimal and requires more effective learning strategies. A similar issue was identified at SMP Negeri 14 Tasikmalaya, where the learning process remains dominated by conventional teaching models with limited use of learning media, resulting in students having

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https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

few opportunities to explore and construct concepts independently. Given these conditions, one learning model considered relevant for supporting students' understanding of mathematical concepts is the Discovery Learning model. This model is considered appropriate because it provides students with the opportunity to discover concepts through the processes of exploration, inquiry, and problem-solving. Through the stages of stimulation, problem statement, data collection, data processing, verification, and generalization, students are actively engaged in the learning process, thereby enabling the development of a deeper conceptual understanding. This is supported by Juriyah et al., (2025), who state that the discovery learning model emphasizes students' active involvement in discovering concepts on their own through processes of exploration, observation, experimentation, and inference.

However, the use of the Discovery Learning model alone is not entirely sufficient to overcome obstacles in understanding abstract mathematical concepts. This is in line with the opinion of Hermawan et al., (2023), who state that the use of the Discovery Learning model will be more effective if supported by learning media to encourage students to be more active and understand the material well. One effective and efficient technology-based learning tool for supporting the mathematics learning process in an interactive and visual manner is GeoGebra. According to Syahbana (2016), GeoGebra is a dynamic program that provides features for visualizing or demonstrating mathematical concepts and serves as a tool for constructing mathematical concepts. In line with the findings of a study conducted by Birgin & Yazici (2021), the use of GeoGebra can significantly improve students' conceptual understanding. This is reinforced by researchers' findings revealing that discovery learning aided by GeoGebra encourages students to actively construct concepts independently and enhances their mathematical literacy (Sofwatun et al., 2025). Furthermore, the use of GeoGebra-based interactive media has also been shown to have a significant impact on improving conceptual understanding through more interactive and meaningful learning (Maulana et al., 2026). Thus, the connection between Discovery Learning and GeoGebra lies in their ability to facilitate the discovery process, particularly during the verification stage, where students can test and validate their findings through interactive visual representations.

However, research integrating the discovery learning model with GeoGebra to assess mathematical conceptual understanding particularly at the junior high school level in the context of straight line equations remains limited. Therefore, this study offers a novel contribution compared to previous research by examining the integration of the discovery learning model and GeoGebra in the topic of straight line equations, with a focus on five indicators of mathematical conceptual understanding, including: restating a concept that has been learned, Classifying objects based on whether or not they meet the criteria of a concept, applying concepts algorithmically, presenting concepts in various forms of representation, and relating various concepts (internal and external to mathematics). Based on this description, this study was conducted to examine the effect and the percentage of mathematical concept understanding among junior high school students whose learning utilized the discovery learning model supported by GeoGebra. This study is expected to contribute to the development of mathematics learning theory by reinforcing the finding that the Geogebra-assisted discovery learning model can enhance students' understanding of mathematical concepts and strengthen the foundations of constructivist theory, which emphasizes exploration, visualization, interactivity, and students' active roles in the learning process.

GeoGebra-Assisted Discovery Learning

GeoGebra-assisted Discovery Learning integrates the stages of conceptual discovery with the use of dynamic technology to help students explore and construct mathematical concepts.

In this approach, GeoGebra is not only used as a medium for displaying graphs, but as an exploration tool that allows students to manipulate mathematical objects, observe changes, discover patterns, and verify conjectures directly. In the lesson on straight line equations, for example, students use GeoGebra to select several points on a line, record coordinate pairs, and analyze the relationship between changes in the values of x and y until they discover the general form of the straight line equations. Next, students observe changes in the line's slope as the position of a point is shifted and calculate the slope based on the obtained point coordinates. Students then independently construct these lines using GeoGebra features such as "parallel lines" and "perpendicular lines," and observe changes in the slope as the position of the line is altered. During the verification stage, students can enter the derived equation into GeoGebra and compare the graph with their previous predictions. Through these activities, students not only follow the problem-solving procedure but also have the opportunity to discover relationships between concepts through the process of observing, exploring, testing, and drawing conclusions. Thus, the integration of GeoGebra into Discovery Learning provides a learning environment that supports students in developing an understanding of mathematical concepts.

Method

Research Design

This study employed a quasi-experimental design in the form of a posttest-only control group design, aimed at testing the effect of implementing the GeoGebra-assisted Discovery Learning model on students' understanding of mathematical concepts. This design was chosen because the study focuses on the final results after the treatment, so measurements were taken only through a posttest without a pretest. The use of a quasi-experimental design was based on the fact that the researcher did not have full control over external variables, and the selection of subjects was not randomized because the classes had already been assigned by the school. Therefore, existing classes were used as the experimental and control groups. In the implementation, the experimental class received an intervention in the form of Discovery Learning assisted by GeoGebra, while the control class used Discovery Learning without GeoGebra. Subsequently, both groups were given a posttest to measure students' understanding of mathematical concepts. A comparison of the posttest results was used to determine the effect of the intervention. The research design used presented in Table 1.

Table 1. Research Design

A	X	O_1
A	$-$	O_2

A represents the random sample of the class, X represents the treatment in the form of a GeoGebra-assisted Discovery Learning model. O_1 represents the posttest for the experimental class, and O_2 represents the posttest for the control class.

Population and Sample

The population in this study consisted of all eighth-grade students at SMP Negeri 14 Tasikmalaya for the 2025/2026 school year. The research sample was selected using the cluster random sampling technique, a sampling method in which the selected units are entire groups or classes, rather than individuals (Sugiyono, 2019). The sampling process was conducted through a lottery: all class names were written on small pieces of paper, which were then drawn at

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random without replacement until two different classes were selected as the research sample. Based on the results of the drawing, Class VIII-I was designated as the experimental class, which received Discovery Learning instruction supported by GeoGebra, while Class VIII-K served as the control class, which received Discovery Learning instruction without GeoGebra. The number of students in each class, both experimental and control was 30.

Instrument

The research instrument used was a mathematical concept comprehension test in the form of open-ended questions. The instrument was developed based on indicators of mathematical concept understanding, which include restating a concept that has been learned, classifying objects based on whether or not they meet the criteria of a concept, applying concepts algorithmically, presenting concepts in various forms of representation, and relating various concepts (internal and external to mathematics). The research instrument outline is presented in Table 2.

Table 2. Mathematical Concept Comprehension Test Question Outline

Learning Outcomes	Learning Objectives	Indicator
By the end of Phase D, students will be able to present, analyze, and solve problems using linear functions, linear equations, and the slope of a straight line in the Cartesian coordinate plane .	Students are able to correctly identify the general form of a linear equation.	Restating a concept that has been learned Classifying objects based on whether or not they meet the criteria of a concept
	Students are able to apply the concept of the slope of a line and accurately explain the relationship between the slopes of two straight lines.	Applying concepts algorithmically
	Students are able to correctly form the equation of a straight line using a given point and slope.	Presenting concepts in various forms of representation
	Students are able to correctly solve problems involving equations of straight lines passing through a given point and having a known slope.	Relating various concepts (internal and external to mathematics)

Table 3. Posttest on Mathematical Concept Understanding

No	Question
1	A student said that "all equations containing the letters x and y must be equations of straight lines." Determine whether this statement is true or false, explain your reasoning, and provide an example!
2	Consider the following equation: (1) $y = 3x - 2$ (2) $2y = 4x + 6$ (3) $y = x^2 - 1$ (4) $x + y = 5$ (5) $y = \frac{1}{2}$ Without altering the given equations, determine which equations form a straight line when graphed and which do not. Explain your reasoning based on the mathematical properties of each equation!
3	Rina was given the task of drawing a line on the cartesian coordinate plane in a graph paper notebook. Two points, (1,2) and $Q(4,8)$, have been marked on the graph paper. Rina draws a line g that passes through both points. Next, she wants to draw a line h that is perpendicular to line g and passes through point (4,8). Determine the slope of line h!

No	Question
4	Consider the following table, which shows the relationship between study time (x) in hours and the number of problems solved (y). x: 1, 2, 3, 4 y: 5, 9, 13, 17 Based on the data, describe the pattern of relationships that emerges and state those relationships in general terms!
5	In the Cartesian coordinate plane, there are two straight lines, g_1 and g_2. Line g_1 passes through points (1,2) and B(3,6), while line g_2 has a slope of -1 and passes through point C(0,6). Solve this problem to determine the point of intersection of the two lines. Clearly write out the steps of the solution!

Before the test instrument was used in the study, it was first pilot-tested on students outside the study sample to determine the validity and reliability of the items. The step or analyzing the results of the pilot test of the research instrument are as follows:

Instrument Validitty Test

The validity coefficients of the test in this study were determined using Pearson's product moment correlation (r). The formula for Pearson's product moment correlation (r), according to Arikunto (as cited in Salmina & Adyansyah), is as follows.

$$r_{xy} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}}$$

Description:

r_{xy} : Correlation coefficient between variables x and y
X : Score for each test item
Y : Total score
n : Number of respondents

The validity test criteria for test items involve comparing the calculated r value with the table r value at a 5% significance level and a degree of freedom ($df = n - 2$). A test item is considered valid if $r_{count} > r_{table}$, whereas it is considered invalid if $r_{count} \leq r_{table}$. Next, to determine the validity coefficient level for each test item, the interpretation criteria is presented in Table 4.

Table 4. Criteria For The Correlation Coefficient Of Instrument Validity

Correlation Coefficient	Interpretation
$0.81 \leq r_{xy} < 1.00$	Very high
$0.61 \leq r_{xy} < 0.80$	High
$0.41 \leq r_{xy} < 0.60$	Moderate
$0.21 \leq r_{xy} < 0.40$	Low
$0.00 \leq r_{xy} < 0.20$	Very low

The results of the instrument validity test were analyzed using SPSS and are interpreted and presented in Table 5.

Table 5. Instrument Validity Test Results

No	r_{count}	r_{table}	Interpretation	Validity
1	0.929		Very high	Valid
2	0.899		Very high	Valid
3	0.823	0.396	Very high	Valid
4	0.808		Very high	Valid
5	0.810		Very high	Valid

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https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

Based on Table 5, all test items showed a correlation coefficient (r count) greater than the table r value. These results indicate that each test item met the established validity criteria. Thus, the mathematical concept comprehension test instrument is deemed valid and suitable for use as a data collection tool in this study.

Intrument Reliability Test

According to Mahkotawati et al., (2025), the method most commonly used for reliability testing by several researchers is Cronbach's Alpha. The level of reliability is expressed as a value known as the reliability coefficient. Reliability testing uses the Cronbach's Alpha formula as follows.

$$r_i = \left(\frac{n}{n-1}\right)\left(1 - \frac{\sum \sigma_b^2}{\sigma_t^2}\right)$$

Description:

r_i	:	Reliability coefficient
k	:	Number of item
$\sum \sigma_b^2$	:	Sum of item score variances
σ_t^2	:	Total variance

Reliability testing in this study used Cronbach's alpha (α) with the assistance of SPSS Statistics 23. The reliability coefficients obtained were then interpreted as Tabel 6.

Table 6. Criteria For The Correlation Coefficient of Instrument Reliability

Correlation Coefficient	Interpretation
0.81 – 1.00	Very high
0.61 – 0.80	High
0.41 – 0.60	Moderate
0.21 – 0.40	Low
0.00 – 0.21	Very low

The results of the reliability test for the mathematical concept comprehension test instrument were analyzed using SPSS and are interpreted and presented in the following Table 7.

Table 7. Instrument Reliability Test Results

Cronbach's Alpha	Interpretation	Reliability
0.889	Very high	Realiability

Based on Table 7, the Cronbach's Alpha reliability coefficient was found to be 0.889, which falls into the very high category. These results indicate that the instrument has a very high level of consistency and is therefore suitable for use as a data collection tool in this study.

Data Collection

Research data were collected through a mathematical concept comprehension test administered after all instructional treatments had been completed. Before use, the test instrument underwent a validation process by experts as well as pilot testing to determine its validity and reliability. This study involved two classes: an experimental class that received instruction using the GeoGebra-assisted Discovery Learning model, and a control class that received instruction using the Discovery Learning model without GeoGebra. After the instructional process ended, both classes took a posttest to gather data on students' understanding of mathematical concepts. The scoring rubric is presented Tabel 8.

Table 8. Scoring guidelines

Indicators of Mathematical Conceptual Understanding	Description	Score
Restating a concept that has been learned	No answer	0
	Restating the concept by writing only the term or formula without explaining its meaning	1
	Restating the concept using sentences that are still quoted from the book or fail to demonstrate understanding	2
	Restating the concept correctly but without providing an example	3
	Restating the concept completely and correctly in one's own words and providing one appropriate example	4
Classifying objects based on whether or not they meet the criteria of a concept	No answer	0
	Classifies one or two objects correctly, while the rest are incorrect or without justification	1
	Classifies three objects correctly and two incorrectly	2
	Classifies all objects correctly but without providing a justification	3
	Classifies all objects correctly and provides a justification based on the concept's properties	4
Applying concepts algorithmically	No answer	0
	Applies the concept by starting the steps but does not reach the result or is completely incorrect	1
	Applies the concept with some steps correct but the main procedure is incorrect	2
	Applies the concept with correct steps but there is an error in the result	3
	Applies the concept with systematic steps and a correct result	4
Presenting concepts in various forms of representation	No answer	0
	Presents one form of representation but contains errors in procedure or values	1
	Presents one form of representation correctly	2
	Presents two forms of representation but does not reach the result or is completely incorrect	3
	Presents the concept in two forms of representation correctly	4
Relating various concepts (internal and external to mathematics)	No answer	0
	Mentions mathematical concepts but is not yet able to correctly relate them to one another	1
	Demonstrates one correct relationship between concepts	2
	Demonstrates two or more relationships between concepts, but there are still errors in the calculations or final results	3
	Demonstrates two or more correct relationships between concepts to solve the problem	4

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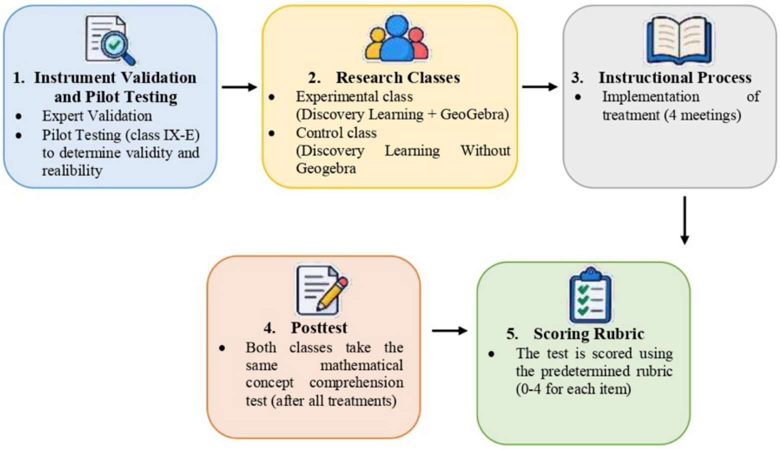

Figure 1. Research procedures

Data Analysis

The data analysis in this study aims to describe the level of students' understanding of mathematical concepts and to test the formulated hypotheses. Through this analysis, a more objective picture of the research results is obtained. The stages of data analysis include descriptive statistics, normality tests, homogeneity tests, and hypothesis testing. Descriptive analysis was conducted by calculating several statistical measures, namely the number of data points, mean, standard deviation, variance, maximum value, and minimum value. Furthermore, the prerequisite analyses in this study included normality and homogeneity tests. The normality test was conducted using the Shapiro Wilk test with a 5% significance level, as it is appropriate for small to medium-sized samples. This test aims to determine whether the research data come from a normally distributed population. Meanwhile, the homogeneity test was conducted using Levene's test at a 5% significance level to determine whether the variances of the data between the experimental and control classes are homogeneous. Next, hypothesis testing was conducted using a test for the difference between two means, specifically the independent samples t-test. The hypothesis tested in this study is: "The Discovery Learning model aided by GeoGebra has an effect on junior high school students' understanding of mathematical concepts". In the final stage, Cohen's d was calculated to measure the effect size resulting from the implementation of the Geogebra-assisted discovery learning model on junior high school students' understanding of mathematical concepts. In addition, to answer the research question regarding the percentage of students' understanding of mathematical concepts who participated in learning using the GeoGebra-assisted Discovery Learning model, students' posttest scores were classified into high, medium, and low categories. This classification is based on the score intervals presented in Table 9.

Table 9. Category of Understanding Mathematical Concepts

Interval	Category
$score \geq \bar{X} + SB$	High
$\bar{X} - SD \leq score < \bar{X} + SB$	Moderate
$score \leq \bar{X} - SB$	Low

Source: (Dewi et al., 2025)

Results

The implementation of the GeoGebra-assisted Discovery Learning model was carried out for the topic of straight line equations over four sessions. The learning process followed the stages of Discovery Learning, namely: stimulation, problem statement, data collection, data processing, verification, and generalization, with GeoGebra integrated into each stage. During the stimulation stage, students observed visualizations of linear graphs, coordinate points, and slopes using GeoGebra to build initial understanding. In the problem statement stage, students formulated problems and initial hypotheses based on their observations. Next, in the data collection stage, students explored using GeoGebra by creating points, drawing lines, and observing changes in the slope and the positions of objects.

In the data processing stage, students analyzed the results of their exploration to identify patterns and mathematical relationships. The verification stage involves retesting the findings using GeoGebra by checking the correspondence between equations and graphs. In the generalization stage, students draw conclusions regarding the equations of straight lines, slopes, and the relationships between lines. Overall, the integration of GeoGebra into learning supports the exploration process and helps students understand concepts more concretely through dynamic visualization.

Figure 2. Implementation of the learning process in the experimental classroom

The statistical analysis of the posttest scores was conducted to determine the effect of the GeoGebra-assisted Discovery Learning model on students' understanding of mathematical concepts. Data on students' understanding of mathematical concepts were obtained through a posttest administered after the entire learning sequence was completed in the experimental and control classes. The test was given to students in Class VIII-I (the experimental class) and Class VIII-K (the control class), each consisting of 30 students. The test instrument consisted of 5 open-ended questions with a maximum score of 20. Based on the posttest results from the experimental class, which received instruction using the GeoGebra-assisted Discovery Learning model, and the control class, which received instruction using the Discovery Learning model without GeoGebra, data were collected and subsequently analyzed descriptively. The results of this descriptive statistical analysis are presented in Table 10.

Table 10. Descriptive Statistics

Class	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Experimental	30	12	6	18	11.10	2.796	7.817
Control	30	15	2	17	8.47	3.776	14.257

The average score for mathematical concept understanding among students in the experimental class was higher than that of the control class, with a difference of 2.63. This

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finding indicates that, descriptively, students who participated in learning using the GeoGebra-assisted Discovery Learning model a better mathematical concept understanding than students who participated in learning using the Discovery Learning model without GeoGebra.

Assumption Testing

Normality Test

A normality test was conducted to determine whether the research data came from a normally distributed population. In this study, the Shapiro–Wilk test was used at a 5% significance level, as this test is appropriate for small to medium sample sizes ($N < 50$).

Table 11. Normality Test Results

Class	Sig.	α	Decision
Experimental	0.463	0.05	H_0 accepted
Control	0.351		H_0 accepted

Based on Table 11, the p-values were 0.463 for the experimental class and 0.351 for the control class. Since the p-values for both groups were greater than 0.05 ($p \geq 0.05$), H_0 was accepted. Thus, it can be concluded that the data on mathematical concept understanding in both the experimental and control classes are normally distributed.

Homogeneity Test

A homogeneity test was conducted to determine whether the variances between the data in the experimental and control groups were equal. In this study, the Levene test was used to assess homogeneity, with a significance level of 5%.

Table 12. Homogeneity Test Result

Sig.	α	Descision
0.155	0.05	H_0 accepted

Based on Table 12, a significance value of 0.155 was obtained. Since this significance value is greater than 0.05 ($sig. \geq 0.05$), H_0 is accepted. Thus, it can be concluded that the variances of the data in the experimental and control groups are homogeneous, or that there is no significant difference in variance between the two groups.

Hypothesis Testing

After all the prerequisites for the analysis were met, the next step was to test the research hypothesis. The test was conducted using an independent samples t-test to compare the mean scores for mathematical concept understanding between the experimental class and the control class.

Table 13. Result of the Independent Sample t-Test

Sig. (2-tailed)	$\frac{1}{2}$ Sig. (2-tailed)	α	Descision
0.003	0.0015	0.05	H_0 rejected

Based on the Tabel 13 results of the independent samples t-test, a one-tailed (right-tailed) hypothesis test was then conducted to determine whether the mean mathematical concept comprehension scores of students in the experimental class were higher than those in the control class. The Sig. (2-tailed) value obtained was 0.003, so the significance level for the one-tailed test was 0.0015. Since this value is less than 0.05 ($0.0015 < 0.05$), H_0 is rejected and H_1 is accepted. Thus, it can be concluded that the mathematical conceptual understanding of students who received instruction using the GeoGebra-assisted Discovery Learning model is better than that of students who received instruction using the Discovery Learning model without GeoGebra.

Effect Size Test

In addition to hypothesis testing, this study also calculated the effect size to determine the extent of the impact of the GeoGebra-assisted Discovery Learning model on students' understanding of mathematical concepts. The effect size was calculated using Cohen's d formula, which aims to provide additional information regarding the strength of the treatment's effect. The result of the effect size calculation are presented in Table 14.

Table 14. Result of Effect Size

Effect Size Cohens'd	
	Posttest
Point Estimate	0.792
Category	Medium

Based on the table of effect size calculations, a Cohen's d value of 0.792 was obtained, which falls into the medium category. This indicates that the GeoGebra-assisted Discovery Learning model has a fairly significant effect on students' understanding of mathematical concepts. Thus, in addition to showing statistically significant differences, the results of this study also indicate that the intervention had a moderate effect on improving the quality of students' understanding of mathematical concepts.

To obtain a more comprehensive picture of students' understanding of mathematical concepts, the research results were further analyzed based on indicators of conceptual understanding and the distribution of students' achievement levels. Based on the analysis of the five indicators of mathematical conceptual understanding, students generally demonstrated adequate performance on each indicator, although there were variations in the depth of their understanding. Some students were able to restating a concept that has been learned, classifying objects based on whether or not they meet the criteria of a concept, applying concepts algorithmically, and presenting concepts in various forms of representation. However, other students still showed limitations, particularly in relating various concepts (internal and external to mathematics). Furthermore, to provide a more detailed picture of the students' level of mathematical conceptual understanding, the posttest scores were classified into high, moderate, and low categories.

Table 15. Frequency distribution of students' understanding of mathematical concepts using a GeoGebra-assisted Discovery Learning model

Interval	Category	Frequency	Percentage(%)
$score \geq 13.90$	High	5	16.67%
$8.30 \leq score < 13.90$	Moderate	21	70.00%
$score \leq 8.30$	Low	4	13.33%
Total		30	100%

Based on Table 15, 16.67% of students fell into the high category of mathematical concept understanding, 70.00% into the moderate category, and 13.33% into the low category. These findings indicate that the majority of students have a moderate level of mathematical concept understanding, with some students having reached the high category. Overall, these

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

results indicate that students' understanding of mathematical concepts tends to be at the moderate to high levels.

The distribution of these mathematical concept understanding categories provides a general overview of students' proficiency levels, but does not fully explain how students understand and solve each test item. Therefore, to gain a deeper understanding, the analysis continued by examining patterns in students' responses to the mathematical concept understanding test items. The analysis results show that students in the high category are generally able to provide complete and systematic answers. They not only write down the solution procedures correctly but are also able to explain the underlying reasons or concepts and present their answers in an appropriate form of representation.

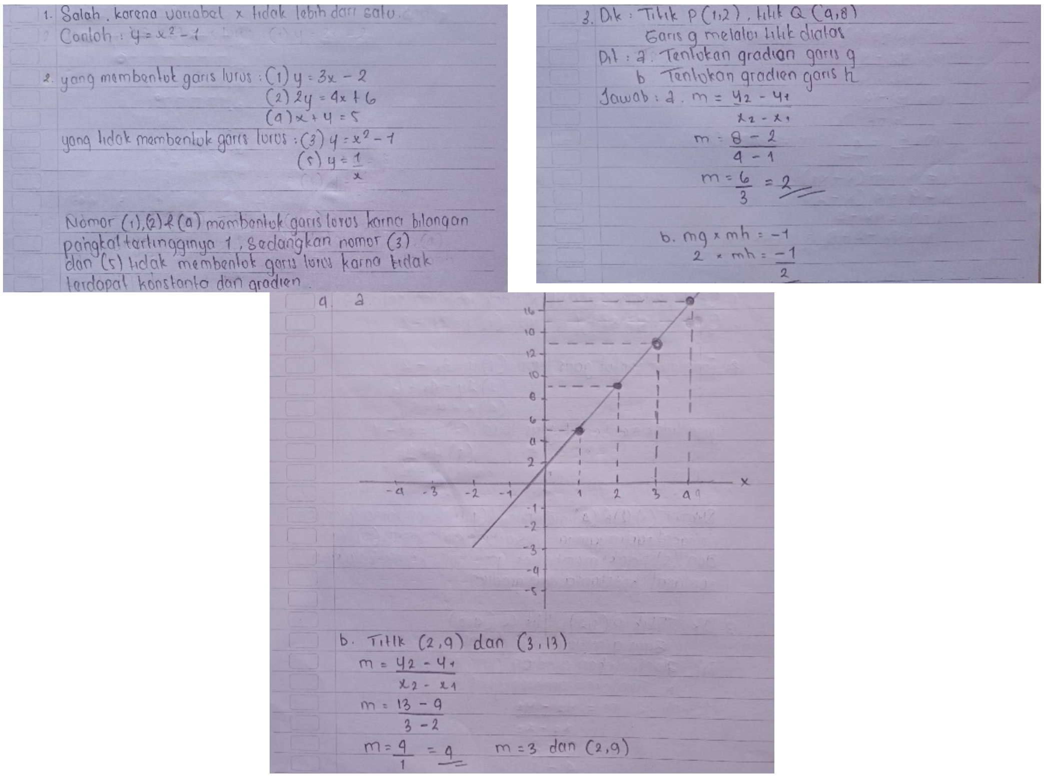

Figure 3. Example of the Correct Answer

Meanwhile, students in the intermediate category tended to be able to solve problems using the correct procedures, but there were still shortcomings in terms of accuracy or the completeness of their explanations. Some students in this category were not yet fully able to connect the concepts used, so the answers they provided were still incomplete. Students in the low category, on the other hand, exhibited various common errors, such as mistakes in performing calculations. In addition, some students provided incomplete answers or only demonstrated two relationships between concepts, yet still made errors in the final calculation.

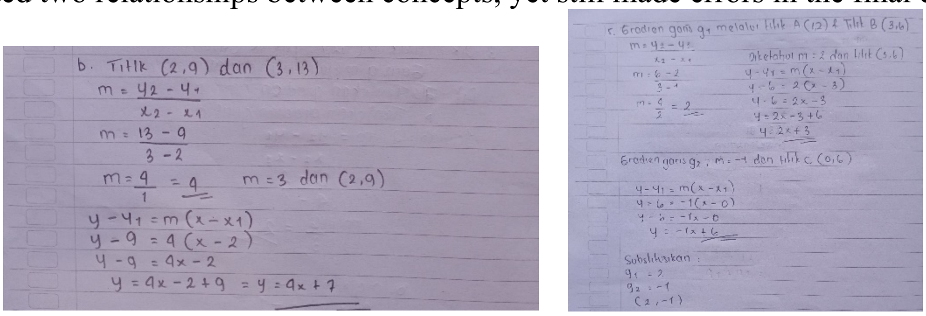

Figure 4. Examples of Inappropriate Answers

Thus, this analysis of response patterns reinforces the results of the previous category distribution, indicating that differences in students' levels of understanding are evident not only from the scores obtained but also from the quality of their answers and the way students construct their understanding of mathematical concepts.

Discussion

The GeoGebra-assisted Discovery Learning model was implemented in the experimental class (VIII-I) over four sessions, while the control class (VIII-K) received instruction using the Discovery Learning model without GeoGebra over the same number of sessions. The results of the data analysis showed that the students' understanding of mathematical concepts in the experimental class was better than that in the control class. This finding indicates that the use of GeoGebra in learning contributes positively to students' understanding of mathematical concepts. This difference in achievement can be explained by the characteristics of the learning process in both classes. Although both classes implemented the Discovery Learning model, students in the experimental class received support in the form of dynamic mathematical visualizations and representations through GeoGebra. These features allowed students to explore relationships between mathematical objects more concretely, observe changes as they occurred in real time, and test the hypotheses they formulated during the concept discovery process. In contrast, students in the control class engaged in concept discovery using more limited learning media, resulting in fewer opportunities for visual and interactive exploration compared to those in the experimental class.

Through the use of GeoGebra, students do not merely receive information passively but are actively engaged in constructing knowledge based on their observations and explorations. This aligns with the characteristics of the Discovery Learning model, which positions students as the primary agents in the learning process and encourages them to discover concepts independently. Thus, the integration of GeoGebra into the Discovery Learning model creates a more interactive and meaningful learning environment, thereby helping students understand mathematical concepts more deeply. These findings align with the views of Radović et al., (2020), who state that technology-based learning with a high level of interactivity can increase students' active engagement in exploratory activities. Such active engagement plays a crucial role in helping students construct knowledge and develop a better conceptual understanding. Therefore, the use of GeoGebra as a supporting tool in the Discovery Learning model can serve as an effective alternative to facilitate the development of students' mathematical conceptual understanding. The results of this study also align with the views of Jerome Bruner, who emphasizes that the learning process should provide students with opportunities to play an active role in acquiring knowledge while taking into account the characteristics and abilities of each individual (Syamsidah et al., 2022). In the context of this study, the application of the Discovery Learning model aided by GeoGebra enables students to construct knowledge independently through exploration, observation, and the discovery of concepts. Through this process, students not only acquire information but are also directly involved in building an understanding of the mathematical concepts being studied.

In the topic of straight line equation, the use of GeoGebra helps students visualize the relationship between slope, coordinate points, and graphical representations dynamically. This interactive visualization makes it easier for students to identify the connections between concepts, thereby making their understanding more meaningful. Additionally, students can explore changes in the slope value or the position of points on the graph and observe the effects

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

directly. Thus, the concept of straight line equation is understood not only as a computational procedure but also as a mathematical relationship that can be represented in various forms. This finding is supported by, Hidayat et al., (2024) who state that GeoGebra is an effective learning tool for supporting students' conceptual understanding. Through its visualization and interactivity features, GeoGebra facilitates students' active engagement during the learning process, thereby helping them more easily grasp abstract mathematical concepts. Therefore, integrating GeoGebra into the Discovery Learning model not only supports the process of conceptual discovery but also strengthens students' understanding of mathematical concepts through a more active, exploratory, and meaningful learning experience.

The results of the study indicate that the implementation of the Discovery Learning model assisted by GeoGebra has a moderate effect on students' ability to understand mathematical concepts. A more detailed analysis based on indicators of conceptual understanding reveals that the strongest indicator is students' ability to applying concepts algorithmically, while the weakest indicator is their ability to relating varous concepts (internal and external to mathematics). Students' strong ability to applying concepts algorithmically indicates that they are relatively capable of following problem-solving procedures and using systematic steps to solve problems. This may be influenced by the characteristics of GeoGebra-assisted Discovery Learning, which provides visual and exploratory experiences, thereby making it easier for students to understand procedures and observe patterns directly. The dynamic visualizations presented by GeoGebra help students understand the solution steps gradually, which ultimately strengthens their algorithmic skills. This finding aligns with a systematic literature review by Zahra & Sudihartinih (2025), which concluded that the integration of GeoGebra into Discovery Learning has a positive impact through interactive and exploratory learning, particularly in supporting students' procedural understanding.

However, weaknesses in the indicator measuring the ability to relating various concepts (internal and external mathematics) suggest that students still face difficulties in achieving a deeper conceptual understanding. Students have not yet been fully able to correctly demonstrate two or more relationships between concepts to solve problems. This indicates that although students have mastered procedural aspects, their relational understanding still needs to be improved. This situation also explains why, overall, students' conceptual understanding remains in the moderate category. When compared to previous studies, the results of this study are consistent with the findings of Jelatu & Ardana (2019), who reported that students who participated in GeoGebra-assisted learning demonstrated better understanding of mathematical concepts than students who learned through conventional methods. Furthermore, Juriyah et al., (2025) state that the Discovery Learning model can support the development of conceptual understanding because it positions students as active participants in the process of discovery and knowledge construction. Student engagement in activities such as observing, identifying patterns, formulating hypotheses, and drawing conclusions enables the formation of more meaningful understanding. This is reinforced by Astrilia et al., (2025), who state that the use of GeoGebra at every stage of Discovery Learning can help students explore and visualize mathematical concepts more effectively.

Nevertheless, the results of this study indicate that the majority of students still fall into the "moderate" category. This does not contradict the finding that the learning process helps students understand concepts; rather, it suggests that the improvement achieved has not yet reached an optimal level. One reason for this is that students are still in the transition phase from procedural understanding to a deeper conceptual understanding. Additionally, time constraints during the exploration process, a lack of scaffolding to guide students in connecting concepts, and students' lack of familiarity with discovery-based learning also contributed to these results. These findings align with those of Maemunah et al., (2025), who stated that improvements in conceptual understanding through Discovery Learning aided by GeoGebra tend to fall into the moderate category, indicating that this approach is effective but has not yet fully optimized higher-order thinking skills. Thus, it can be concluded that the implementation of GeoGebra-assisted Discovery Learning is capable of improving students' understanding of mathematical concepts, particularly in procedural aspects. However, to achieve a high level of understanding, further efforts are needed, such as designing more targeted learning activities, providing adequate scaffolding, and emphasizing the ability to connect various concepts so that students can develop a deeper and more integrated conceptual understanding. In addition, teachers also need to incorporate probing and reflective questions that can help students connect the concepts they are learning, both within the context of mathematics itself and to real-world situations. With well-designed activities and appropriate scaffolding, the use of GeoGebra in Discovery Learning can be optimized to help students achieve a higher level of conceptual understanding.

Implication of findings

The results of this study have implications for mathematics teaching practices, particularly regarding the implementation of GeoGebra-assisted Discovery Learning. The findings indicate that the integration of GeoGebra can support students' understanding of mathematical concepts, especially their ability to apply concepts algorithmically, which was the indicator with the highest achievement score. However, the use of GeoGebra is insufficient if it is utilized solely to display graphs or visualizations of mathematical objects. Teachers need to design GeoGebra activities that are purposeful and integrated with each stage of Discovery Learning, such as providing opportunities for students to manipulate objects, observe changes, discover patterns, make conjectures, and verify their findings. In this way, GeoGebra can function as an exploration tool that supports the process of conceptual discovery, rather than merely serving as a medium for presenting material.

Findings regarding low achievement on indicators that relating various concepts (internal and external to mathematics, also have important implications for the design of learning activities. Teachers need to pay more attention to activities that explicitly encourage students to connect concepts, such as relating slope to graphs, coordinates, the form of a line equation, and contextual problems. Prompting questions, exploratory tasks, and reflective activities can be used to help students explain the relationships between concepts and build a more integrated understanding. This is important because, although the instruction had a moderate effect, the majority of students (70.00%) still fell into the moderate category. Therefore, GeoGebra-assisted instruction must be accompanied by adequate scaffolding so that students are not only able to follow the problem-solving procedures but also understand the underlying conceptual relationships. Furthermore, these findings suggest that the development of technology-assisted learning should take into account not only the overall final outcomes but also the achievements on each indicator of conceptual understanding. Future research could develop more specific GeoGebra activities to strengthen indicators that remain weak, particularly the ability to relate various concepts and classify objects based on conceptual criteria. Furthermore, studies with longer learning durations, larger samples, or different research designs could be conducted to obtain a more comprehensive picture of the effectiveness of integrating Discovery Learning and GeoGebra in developing students' mathematical conceptual understanding.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i3.5373 Volume 6, No 3, July - September 2026, pp. 1376 –1395

Conclusion

The findings indicate that eighth-grade students who learned straight-line equations through GeoGebra-assisted Discovery Learning achieved higher mathematical conceptual understanding than those who learned through Discovery Learning without GeoGebra. The experimental group also showed a substantial between-group advantage, supporting the instructional potential of integrating dynamic mathematical representations into discovery-oriented learning. Within the experimental group, 16.67% of students were categorized as having high conceptual understanding, 70.00% moderate understanding, and 13.33% low understanding. The predominance of the moderate category indicates that variation in students' conceptual understanding remained, particularly in relating various concepts (internal and external to mathematics) and classifying objects based on whether or not they meer the criteria of a concept. These findings should be interpreted within the scope of the study. The intervention involved a relatively short learning period, a limited sample from a single school, and a posttest-only quasi-experimental design, which restricts direct conclusions about changes in students' understanding from before to after the intervention. Future studies should therefore employ pretest-posttest designs, involve students from multiple schools, and examine how GeoGebra-supported discovery activities influence specific dimensions of conceptual understanding. Particular attention could be given to how students coordinate graphical, symbolic, and verbal representations of straight-line equations. For classroom practice, teachers can use GeoGebra not merely as a visualization tool but as part of structured discovery activities in which students manipulate representations, formulate and test conjectures, connect mathematical concepts, and justify the relationships they identify.

Conflict of Interest

The authors declare no conflict of interest.

Auhor Contributions

R.L. conceptualized the research idea, designed the study, conducted the data collection, performed the data analysis, and drafted the manuscript as part of the undergraduate thesis. Y.H and I.N supervised the research process, provided guidance in the development of the methodology and theoretical framework, reviewed and revised the manuscript, and approved the final version of the work. All authors confirm that they have read and approved the final version of this manuscript. The percentage contributions for the conceptualization, drafting, and revision of this paper are as follows: R.L: 50%, Y.H: 25%, and I.N: 25%.

Data Availability Statement

The authors declare that data sharing is not applicable, as no new data were created or analyzed in this study.

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