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Mathematical Concept Understanding of Middle School Students: An Experimental Study of the Discovery Learning Model

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ABSTRACT

The role of conceptual understanding is essential because it enables students to more easily comprehend and learn mathematics. Therefore, this study focuses on the impact of the Discovery Learning model on the mathematical concept comprehension of students at a public middle school. The research employed an experimental method with a posttest-only control group design. The study's population included all eighth-grade students at public middle school 8 Gorontalo. The sample consisted of class VIII-5 as the experimental group, which implemented discovery learning, and class VIII-3 as the control group, which used a direct instruction learning model. Data was collected through an essay test administered as a post-test at the end of the study. Data analysis was performed descriptively and inferentially using a t-test. The results of the t-test indicated a t-calculated value of 3.506 and a t-table value of 1.6779, confirming that the t-calculated value is greater than the t-table value. Thus, it can be concluded that the Discovery Learning model has a significant influence on the mathematical concept comprehension of eighth-grade students at public middle school 8 in Gorontalo.

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1. INTRODUCTION

The current role of education is becoming increasingly important for innovation, development, and human empowerment, as it aims to shape individuals to be superior and better prepared for the future (Batubara, 2020). Education is one of the factors that determines whether a country progresses or not (Rahmah, 2023; Shavkidinova et al., 2023).

Mathematics is a branch of science that plays a role in developing thinking skills and reasoning abilities (Maass et al., 2019; Abd Algani, 2022). This is due to the role of mathematics in daily life, as it equips individuals with problem-solving skills and contributes to the advancement of science and technology. Teachers need to creatively design learning plans to ensure that mathematics learning achieves its intended goals (Prabowo et al., 2022; Albay & Eisma, 2025). These plans should enable the creation of

interactive learning, encouraging students to actively participate in the learning process. In the context of practical implementation, teaching methods commonly applied in many educational institutions tend to focus on textbook use and often lack relevance to students' everyday experiences (Gebre, 2022). This condition indicates a dissonance between the teaching materials and students' real-life contexts, which may reduce their engagement and contextual understanding of the material being taught.

Serrano Corkin et al. (2019) assert that a student-centered approach to learning is ideal, as a teacher-centered approach may hinder students' development. Additionally, Possessing conceptual understanding is a crucial skill for learning mathematics (Kusumadewi et al., 2020). Mathematical conceptual understanding refers to the ability to master material, where students not only recognize or memorize concepts but can also apply them to various situations in ways that are easier for them to understand (Simon, 2017; Cai & Ding, 2017). This aligns with the opinion of Fritz et al. (2019), who stated that difficulties in understanding mathematical concepts constitute a significant portion of the challenges in learning mathematics. One of the main goals of learning mathematics is mathematical understanding, in which students truly comprehend the concepts being taught, rather than merely memorizing them (Thanheiser & Melhuish, 2023).

The role of conceptual understanding is essential because it enables students to more easily comprehend and learn mathematics (Copur-Gencturk, 2021). Each learning session is designed to strengthen conceptual understanding, which serves as a crucial foundation for students to develop other essential skills, such as logical thinking, communication, and problem-solving. According to Sun and Xie (2020), mastery of concepts is the key to achieving learning objectives. Students' ability to fundamentally understand mathematical concepts significantly influences their success in mastering mathematics as a whole. Thus, emphasizing conceptual understanding not only supports content mastery but also equips students with broader and more adaptive cognitive skills. To ensure students understand mathematical concepts, the learning process must provide opportunities for them to actively participate in constructing them (Abramovich et al., 2019).

This study refers to indicators of conceptual understanding (Setyaningrum,, 2018), which include (1) restating the concept and (2) using effective strategies to understand a concept involving three main steps: first, identifying both relevant and irrelevant specific cases related to the concept; second, distinguishing between examples and non-examples to clarify its boundaries; and third, representing the concept through various mathematical formats.

A learning model can be defined as a methodology or a series of stages implemented in the teaching and learning process to achieve learning objectives or competencies more effectively and efficiently (Morrison et al., 2019). This activity includes teacher guidance in organizing student activities, such as seeking information, classifying, investigating, and exploring. Hooshyar et al. (2019) share a supportive view, stating that a learning model is considered an approach that encourages students to actively explore

and analyze learning material independently. As a result, the learning outcomes tend to last longer in memory, and students are less likely to forget them easily (Seel, 2017).

A learning method is needed that is not only oriented toward the transfer of information from teacher to student but also encourages active student participation in discovering and developing their own ideas. This aligns with the opinion of Safapour et al. (2019), who stated that an enjoyable teaching and learning process can be achieved by applying various models, strategies, approaches, methods, and learning media.

A preliminary study conducted by the author, which included an interview with a mathematics teacher, revealed that direct instruction was occasionally used, despite the application of various learning models. In the explanation, the teacher stated that one of the factors contributing to students' low conceptual understanding of mathematics can be seen in the results of daily tests on the Linear Equations in Two Variables material. In class VIII-1, out of 31 students, only 9 met the minimum competency standard for completion criteria, while the remaining students did not meet that standard. ard. At Public Middle School 8 Gorontalo, the minimum completion criteria score stands at 75. This phenomenon occurred because students tend to focus on practicing problem-solving skills without being supported by a deep conceptual understanding. Additionally, they perceive mathematics problems as difficult to solve.

To optimize students' conceptual understanding of mathematics, it is essential to implement a learning model that encourages active student participation. One approach that has proven effective in increasing engagement during the learning process is the Discovery Learning model (Manurung & Pappachan, 2025).

The discovery learning model actively involves students in the learning process and encourages them to independently discover concepts, understandings, and problem-solving strategies (Palinussa et al., 2023; Hariyanto et al., 2023). Its learning stages consist of a series of steps, including preparation, simulation, problem identification, data collection, information processing, the process of verification, and finally, drawing overall conclusions. As facilitators or guides, teachers also play a role in this process. A paradigm shift in education must be realized—moving from a teacher-centered approach to one that places students at the center of the learning process (Matsuyama et al., 2019).

Discovery learning is a model designed to encourage active student participation in independent exploration and investigation (Novantri et al., 2020). As a result, this learning approach can produce outcomes that help students retain their learning for a longer time. Based on the conceptual framework and in line with the stages of systematic scientific methodology, the implementation of the discovery learning model in lesson design can be explained in detail (Ellizar et al., 2018; Wulandari et al., 2018). This procedure fundamentally involves a series of sequential steps, beginning with the simulation or presentation of a problem. This stage is essential, as it serves as an initial stimulus that sparks students' curiosity and prepares them to engage in the discovery process. Next, students are directed to identify problems within the simulation or scenario, encouraging them to formulate key questions that need to be investigated. This process is then followed by data collection, where students actively seek information,

conduct observations, or perform experiments to obtain relevant data. The collected data then undergoes a data management stage, which involves organizing and analyzing the information found. The next crucial step is verification, where students test their hypotheses or assumptions based on the processed data, often involving discussions and collaboration among students. Finally, this entire process culminates in drawing conclusions, where students formulate their own understanding of the concepts or principles being studied.

Thus, this study has the crucial objective of providing strong empirical evidence regarding the effectiveness of discovery learning as an alternative learning model that is more adaptive and empowering for students. The results of this research are expected not only to enrich the body of knowledge in the field of mathematics education but also to serve as a foundation for educators at public middle school 8 Gorontalo and other educational institutions to adopt a more participatory and student-centered approach, thereby creating a more meaningful and effective mathematics learning experience.

2. METHOD

This study uses an experimental method as the main foundation, with a posttest-only control group design. Class X receives special treatment (implementing the Discovery Learning model), while the other class does not. The study's population included all eighth-grade students at public middle school 8 Gorontalo. The sample consisted of class VIII-5 as the experimental group, which implemented discovery learning, and class VIII-3 as the control group, which used a direct instruction learning model. Table 1 and Figure 1 present the following research model.

Table 1. Research Design

Class	Treatment	*Post test*
Experiment	X_1	O
Control	X_2	O

Description:
X1: Learning using Discovery Learning
X2: Learning using the Direct Instruction model
O: Posttest for the experimental and control class

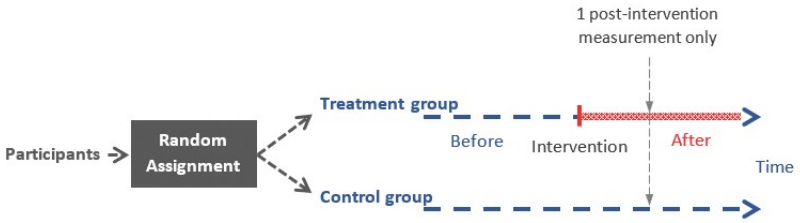

Figure 1. Research Design Chart

This study requires data on students' level of understanding mathematical concepts related to the topic of systems of linear equations in two variables. This data is obtained through a test instrument designed according to indicators of conceptual understanding. The test is administered at the end of the study (post-test) in essay format. To complete this test, the indicators of conceptual understanding used are (1) reconceptualization of ideas, which involves restating a concept in a different way; (2) illustration through examples and non-examples, where the concept is explained by providing both relevant and irrelevant cases; and (3) representation of the concept using various mathematical formats, which involves depicting the concept through diverse forms of mathematical expression.

3. RESULTS AND DISCUSSION

Results

This study was conducted carefully at public middle school 8 in Gorontalo, ensuring the relevance of the timing and the ongoing educational context. The initial stage of this research began with a direct preliminary observation at the research site. The learning outcome data analyzed in this study include the experimental class, which applied the discovery learning model, and the control class, which applied the direct instruction model in mathematics lessons on the system of linear equations in two variables material at public middle school 8 Gorontalo. The description of student learning outcomes from both groups is presented in Table 1 below.

Table 1. Description of Learning Outcome Data

Data	Class	N	Min. Score	Max. Score	Mean	Median	Modus	St Dev
Post-test	E	23	2	8	5,54	5,88	6,24	1,58
	K	26	1	7	3,73	3,61	3,17	1,90

Test results in the experimental class: out of 23 students, the maximum score obtained was 8 and the minimum score was 2. Meanwhile, in the control class, out of 26 students, the maximum score was 7 and the minimum score was 1. This indicates that the use of the discovery learning model had an impact on students' conceptual understanding of mathematics at public middle school 8 in Gorontalo.

Normality Test

This test was conducted to determine whether the research data is normally distributed or not, using the Lilliefors test, with the testing criterion being to accept H_0 if the calculated L value (Lhitung) is less than the critical L value (L-tabel) at a significance level of $\alpha = 5\%$.

Table 2. Result of The Data Normality Test

Class	Data	N	L_{Hitung}	L_{Tabel}	Criteria
Experiment	Posttest	23	0,160	0,185	Fail to reject H_0
Control		26	0,168	0,174	Fail to reject H_0

Homogenity Test

This test aims to determine whether the variance of the research data is homogeneous or not in the experimental and control classes. The homogeneity of variance test used here is the F-test, with the criterion that H_0 is accepted if the calculated F value (Fhitung) is less than the critical F value (Ftabel) at a significance level of $\alpha = 5\%$, meaning that both sample groups have homogeneous variances.

Table 3. Results of Homogeneity of Variance Test

Data	Class	N	Variance	F_{Hitung}	F_{Tabel}	Criteria
Posttest	Experiment	23	2,79	1,26	1,98	Fail to reject H_0
	Control	26	3,53			Fail to reject H_0

Hypothesis Test

In this study, a two-sample t-test was used to analyze the effect of applying the discovery learning model on students' understanding of mathematical concepts in the topic of systems of linear equations in two variables. The results of the two-sample t-test calculation are presented as follows.

Table 4. Hypothesis Testing in the Reseach

Cluster	Average	Variance	Dk	T_{hitung}	T_{Tabel}
Experiment	5,61	4,97	47	3,506	1,6779
Control	3,61	3,10			

Building upon the table above, the critical t value (ttable) is 1.6779 with degrees of freedom (df) = 47 at a significance level of 0.05, and the calculated t value (tcalculated) is 3.506. The rejection of H occurs because tcalculated is greater than ttable, specifically 4.637 > 2.0106.

Discussion

This study was conducted to compare the understanding of mathematical concepts among 8th-grade students at public middle school 8 in Gorontalo who were taught using the discovery learning model and the direct instruction model. The findings of the study revealed that the average conceptual understanding of students taught with the discovery learning model reached 5.61, while those who received direct instruction had an average

score of 3.61. The significant difference indicates the effectiveness of the discovery learning model in enhancing students' understanding of mathematical concepts.

Before these data were obtained, validity and reliability tests were first conducted to ensure the appropriateness and alignment of the test with the material and the intended learning objectives. Out of 7 test items analyzed, 5 were declared valid. After obtaining valid results, the test was administered to two classes selected as the experimental and control groups. Class VIII-5 was designated as the experimental class implementing the discovery learning model, while Class VIII-3 served as the control class implementing the direct instruction model.

Throughout the learning process in the experimental class, students actively participated and were directly involved, both in group discussions and in completing tasks using student worksheets. The teacher acted as a facilitator by providing guidance and support to the students. According to research conducted by Tanjung et al. (2020), the discovery learning model encourages students to actively participate in group discussions to discover and develop their ideas, which are then used to solve problems. This model fosters students' learning independence and effectively improves their learning outcomes. The improvement in students' understanding of mathematical concepts could be seen in the way they approached and understood the given problems through the steps of discovery learning (Kartika, 2020; Maifi & Ahmad, 2021).

At the simulation stage, students were presented with problems found in the student worksheet. This stage played a role in creating a learning interaction that fostered students' curiosity to investigate the problems they faced. The stage that contributed to improving mathematical concept understanding was when students were able to construct mathematical models based on the word problems in the student worksheet. This improvement was also supported by the opportunity given to students to identify information during the problem formulation stage, enabling them to understand the available elements as well as what needed to be found in the problem. At this stage, the teacher served only as a facilitator, supporting and guiding students who faced difficulties in learning.

Next, during the data processing stage, students were guided and directed to independently discover how to determine the solution to the given problems through the student worksheets. The following stage is verification, where students were guided to recheck their answers to ensure accuracy. This stage also trained students to be more thorough in solving problems.

In contrast, during the learning process in the control class, students were taught using the direct instruction model, where the teacher explained and presented information directly to the students. This approach led to a low level of student engagement in the learning process, as they merely listened to the explanations, focused on taking notes, and tended to be passive during the lesson. One of the main weaknesses of the direct instruction model is the lack of student involvement (Eppley & Dudley-Marling, 2019). When students only listen to explanations without actively participating, they tend not to develop a profound understanding (Wu & Schunn, 2023).

These findings are consistent with research conducted by Rahayu and Kuswanto (2021), which found that in the implementation of the direct instruction model, the teacher was highly dominant, resulting in students being completely passive during the lesson—playing with their peers when given tasks and showing little enthusiasm for learning mathematics. This ultimately led to a lack of understanding among students in mastering mathematical concepts during the learning process.

In general, this study reveals that applying the discovery learning model has a significant positive impact on students' understanding of mathematical concepts. By engaging students in exploration and discovery, this model not only enhances cognitive understanding but also sharpens critical and creative thinking skills, which are essential in learning mathematics (Nilimaa, 2023). On the other hand, the direct instruction model tends to result in less in-depth understanding and reduces student engagement in the learning process (Dignath & Veenman, 2021). Therefore, to improve students' learning outcomes in mathematics, it is necessary to implement a more interactive and experience-based approach.

4. CONCLUSION

Based on a comprehensive evaluation of the collected data and significant findings from this study, it can be concluded that there is a striking and meaningful disparity in the level of mastery of mathematical concepts among eighth-grade students at public middle school 8 Gorontalo. This performance discrepancy is clearly identified when comparing the group of students taught using the Discovery Learning model with their peers who received instruction through the direct teaching method. More than just a difference, this study strongly indicates a more substantial and progressive improvement in conceptual understanding capabilities among eighth-grade students at public middle school 8 Gorontalo who actively participated in learning sessions implementing the Discovery Learning model.

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