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GeoGebra in Discovery Learning: Alternative Solutions for Understanding Mathematical Concepts

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ABSTRACT

In learning, students are required to understand the concepts of problems and visualize the objects of mathematical learning discussions. However, in reality, students face difficulties in understanding and visualizing the objects discussed; learning media can help solve the problems faced by students so that the learning process is no longer conventional, which causes students to be passive. This research aims to determine whether there is an effect of GeoGebra learning media on the Discovery Learning model on students' understanding of mathematical concepts. This research uses a quasi-experimental quantitative method that tests the cause and effect between variables. The study was conducted in class XI MIA MAL UINSU as the population, with sampling carried out by randomizing classes. The sample for this study consisted of students from class XI MIA 1 as the control class and XI MIA 2 as the experimental class. Each class consists of 39 students. The instrument used is a mathematical concept understanding ability test in the form of an essay, consisting of a pretest and a posttest. The data collected were then tested using a t-test. Based on the t-test calculations with $\alpha = 0.05$, the significance value obtained is 0.000, thus $0.000 < 0.05$. It can be concluded that GeoGebra learning media has an effect on the Discovery Learning model on students' concept understanding. The research results regarding the impact of learning media on students' concept understanding indicate that teachers can implement this learning media in their teaching.

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1. INTRODUCTION

Mathematics is one of the disciplines that plays an important role in developing science and technology [1]. Mathematical skills are needed in the academic world and everyday life, such as in decision making, problem solving, and data analysis [2]. Therefore, mastery of mathematical concepts becomes one of the fundamental competencies that students must possess. However, in reality, many students experience difficulties in understanding mathematical material, particularly geometric transformations [3].

Geometric transformations as part of the geometry material require visualization skills, understanding abstract concepts, and the ability to relate these concepts to concrete representations [4]. Based on the results of initial observations through interviews with the mathematics teacher, it was found that students struggle to visualize transformed geometric objects, do not understand the problems being discussed, and have a weak grasp of the underlying basic concepts [5]. This difficulty is exacerbated by the still conventional learning, where the teacher is the center of information (teacher-centered) and students only play the role of knowledge recipients. This condition makes students passive, less explorative, and not actively involved in concept discovery [6].

Several previous studies, such as those conducted by Siahaan, show that geometry is important in connecting abstract and concrete concepts. Nevertheless, students still face difficulties determining the steps to solutions, reading fewer learning resources, and rarely using supportive learning media [7]. This aligns with the views of Nasution & Dewi, who emphasize that understanding mathematical concepts requires students' skills in analyzing information, making decisions, and using it to solve problems [8]. Thus, a learning model that can actively engage students is needed, one of which is Discovery Learning.

As stated by Atmaja [9], Discovery Learning emphasizes student involvement in discovering concepts through exploration, observation, investigation, and independent conclusion drawing. Through this model, learning is expected to be more meaningful because students are directly involved in knowledge discovery. To support the implementation of Discovery Learning, interactive and visual learning media are essential, one of which is GeoGebra [10].

GeoGebra is a dynamic mathematics software that can integrate algebra, geometry, and calculus interactively. The use of GeoGebra has proven effective in facilitating students' understanding of abstract concepts through dynamic visualization and encouraging creativity and critical thinking skills. Research by Karomah et al. [11] shows that the use of GeoGebra positively impacts the understanding of mathematical concepts, particularly in the material of geometric transformations. However, previous studies generally only highlighted the effects of GeoGebra or Discovery Learning separately, while research on integrating both as a verification medium in enhancing students' conceptual understanding is still limited.

The novelty of this research lies in integrating the use of GeoGebra in the Discovery Learning model as a means of conceptual verification, which has not been widely explored in previous research. Most previous studies only examined the effects of GeoGebra or Discovery Learning separately, without assessing how combining both can simultaneously enhance the understanding of mathematical concepts, particularly in geometric transformations. Thus, this research offers a new approach that combines active learning models and interactive technology, and provides empirical evidence regarding the effectiveness of this integration in supporting more meaningful and comprehensive mathematics learning for students.

2. METHOD

This research uses a quantitative approach with a quasi-experimental design. The quasi-experimental design is chosen because this study aims to determine the effect of a certain treatment on the dependent variable, but it is impossible to have full control over all external variables that may influence the research results [12]. This quasi-experimental design uses a pretest-posttest control group design, which involves two groups, namely the experimental class and the control class. Both groups are given a pretest to determine their initial abilities, then given different treatments, and concluded with a posttest to see the improvement in learning outcomes [13].

This research was conducted in the XI MIA class of the Madrasah Aliyah Laboratorium (MAL) UIN Sumatera Utara Medan for the 2024/2025 academic year. The study population consists of all XI MIA students, including four classes with 159 students. The sampling technique used was purposive sampling, which is the selection of samples based on specific considerations aligned with the research objectives [14]. Based on the election results, two classes were designated as samples, namely: class XI MIA 1, consisting of 39 students (20 male and 19 female) as the control class, and class XI MIA 2, consisting of 39 students (18 male and 21 female) as the experimental class.

The research instrument used was a mathematical concept understanding test in the form of a pretest and posttest. The test consists of 8 essay questions that have been validated by experts, covering three indicators of concept understanding, namely: (1) the ability to restate the concepts that have been learned, (2) the ability to present concepts in various mathematical representations, and (3) the ability to distinguish examples from non-examples of a concept [15].

The treatment given to the experimental class is learning with the Discovery Learning model, assisted by GeoGebra, on the subject of geometric transformations. The Discovery Learning model was chosen because it emphasizes the process of concept discovery through exploration, data collection, and generalization, allowing students to construct knowledge independently [12]. The learning syntax used consists of six main steps: (1) stimulation, (2) problem statement, (3) data collection, (4) data processing, (5) verification, and (6) generalization. Students are provided with Student Work Sheets (LKPD) according to this model's syntax to support learning. At the verification stage, GeoGebra is utilized to help students visualize geometric transformations dynamically and interactively.

Meanwhile, the control class used a conventional learning model with a lecture approach and exercise problems. The pretest and posttest data from both classes were then analyzed using an independent t-test with the help of statistical software. This analysis aimed to determine whether there was a significant difference in mathematical concept understanding between the class taught with Discovery Learning assisted by GeoGebra and the class taught with conventional learning [13]. The data collected from the pretest-posttest was then analyzed using the t-test, as shown in Figure 1.

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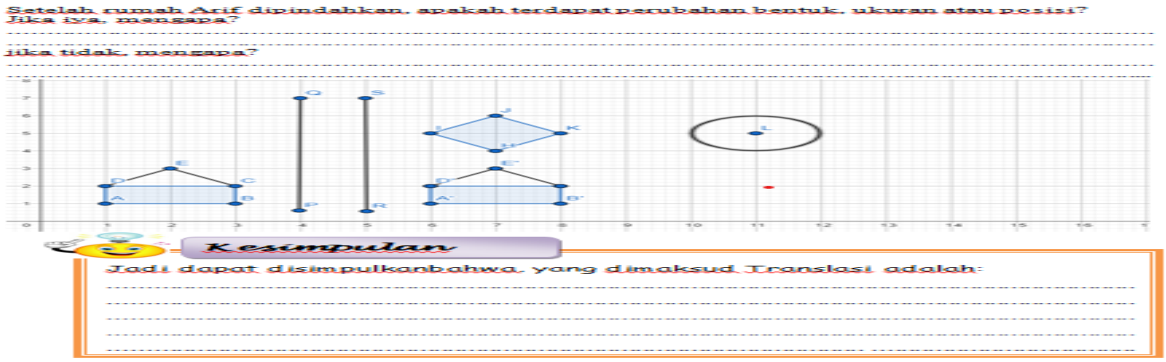

Figure 1. GeoGebra display on the LKPD

3. RESULTS AND DISCUSSION

3.1. Results

In the Stimulation stage, the teacher presents an event or phenomenon relevant to the learning material as an initial trigger for students. The main goal of this stage is to awaken students' motivation, curiosity, and interest in learning so that they are more prepared to enter the following learning process. The event serves as a cognitive stimulus and an affective trigger that connects the learning experience with the students' real lives. Thus, students are encouraged to actively observe, ask questions, and build initial assumptions about the concepts to be learned. This process can be seen in Figure 2, where students show engagement through expressions of curiosity and participation in responding to the stimulus provided by the teacher.

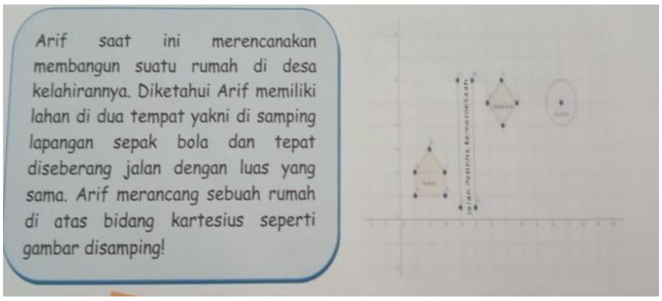

Figure 2. Stimulation

In the Problem Statement stage, the teacher begins to guide students in identifying issues related to the phenomena or events that have been previously presented. This process aims for students to receive information passively and actively engage in discovering the core issues that will be studied. The teacher poses open-ended questions to stimulate students' critical and analytical thinking abilities. Subsequently, students are asked to formulate initial conjectures or preliminary answers (hypotheses) based on their understanding and knowledge. This activity trains scientific thinking skills while familiarizing students with viewing a problem from various perspectives. Students' involvement at this stage is evident in Figure 3, where they actively interact in expressing ideas and potential answers to the problems posed by the teacher.

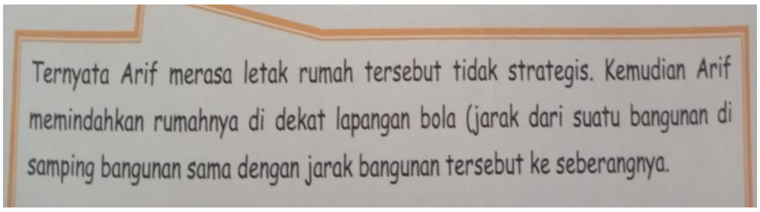
Ternyata Arif merasa letak rumah tersebut tidak strategis. Kemudian Arif memindahkan rumahnya di dekat lapangan bola (jarak dari suatu bangunan di samping bangunan sama dengan jarak bangunan tersebut ke seberangnya.

Figure 3. Problem Statement

In the Data Collection stage, students are directed to gather relevant information, facts, and data to test the preliminary answers or hypotheses they formulated in the previous stage. This process requires students' observation skills, seeking information sources, and systematically recording their findings. This data collection activity also trains students to work meticulously, objectively, and based on tangible evidence, not just assumptions. The data collection results are then used as the basis for answering questions posed by the teacher, enabling students to develop scientific and evidence-based thinking. From the activities carried out, it is evident that students actively write down the data obtained and organize it into more directed responses. This is shown in Figure 4, where students demonstrate real involvement in processing information as an important step towards understanding the concepts being taught.

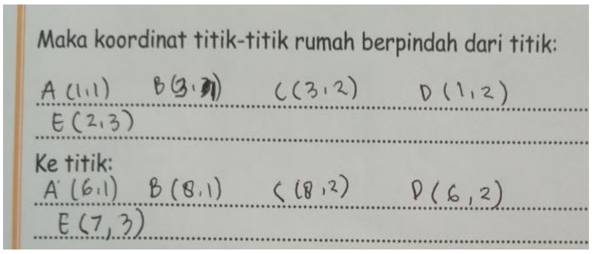
Maka koordinat titik-titik rumah berpindah dari titik:
A (1,1) B(3,1) C(3,2) D (1,2)
E (2,3)
Ke titik:
A' (6,1) B (8,1) C (8,2) D (6,2)
E (7,3)

Figure 4. Data Collection

In the Data Processing stage, students begin analyzing the data they have previously collected. This activity focuses on connecting information, identifying patterns, and seeking relationships among data to be used as a basis for answering the formulated problems. This process requires critical, logical, and systematic thinking skills, as students do not simply record data but interpret its meaning to gain a deeper understanding. Thus, students learn to construct evidence-based arguments and build more rational answers. From observations, it is clear that students can analyze and connect data accurately, allowing them to find solutions to the given problems. This activity is illustrated in Figure 5, where students demonstrate active engagement in processing data as an important part of the problem-solving process.

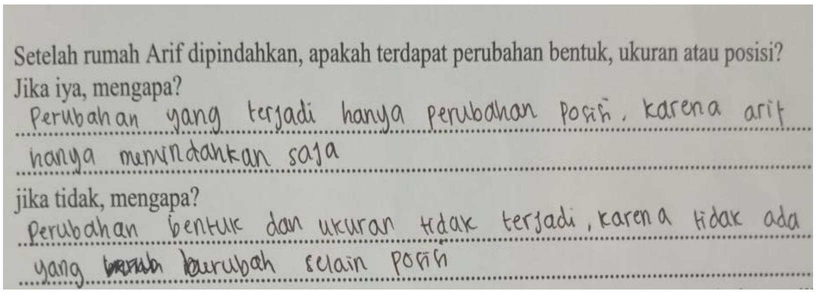
Setelah rumah Arif dipindahkan, apakah terdapat perubahan bentuk, ukuran atau posisi?
Jika iya, mengapa?
Perubahan yang terjadi hanya perubahan posisi. karena arif hanya memindahkan saja
jika tidak, mengapa?
Perubahan bentuk dan ukuran tidak terjadi, karena tidak ada yang berubah selain posisi

Figure 5. Data Processing

In the Verification stage, students are guided to prove the answers or hypotheses they have formulated based on previous data analysis results. This verification process aims to ensure the validity and accuracy of the answers obtained so that students cannot merely assume but also test the outcomes of their reasoning objectively. In this learning process, the teacher facilitates verification by displaying the GeoGebra application as a supporting medium. Through GeoGebra, students can visualize mathematical concepts more concretely, re-check the connections between data, and identify the correspondence between the analysis results and applicable theories or principles. Students can assess whether the proposed solutions are correct, close to correct, or need improvement. This activity is shown in Figure 6, where GeoGebra is used to validate students' answers, making the learning process more valid, interactive, and technology-based.

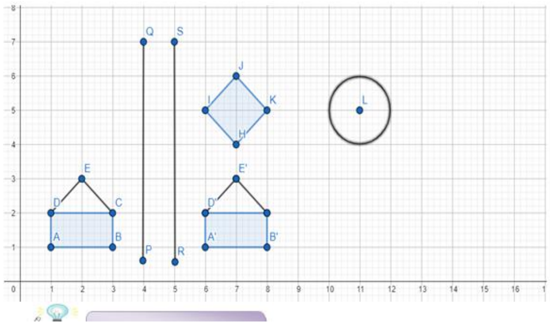

Figure 6. Verification

In the Generalization stage, students are directed to conclude the entire learning process they have gone through. This activity is the peak of the inquiry sequence, where students not only understand the answers to the posed problems but also can formulate general principles that can be applied in similar contexts. The generalization process requires students to connect the initial phenomenon, the data obtained, and the analysis results to the evidence presented, leading to a more comprehensive and meaningful understanding. Thus, students acquire new theoretical knowledge that applies to everyday life. The learning outcomes show that students can compile conclusions coherently and logically based on both group and individual work. This is reflected in Figure 7, where students demonstrate the ability to present the results of generalization as evidence that the learning objectives have been achieved.

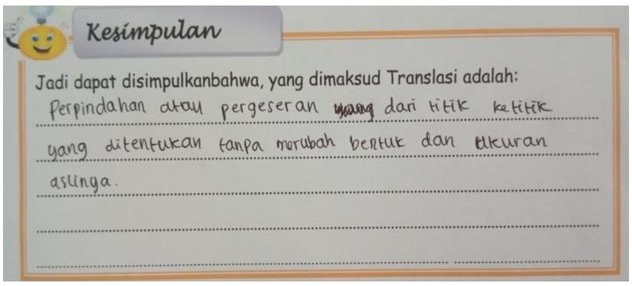

Figure 7. Generalization

The following presents the analysis results of students' concept understanding processed using SPSS in Table 1.

Table 1. Paired Samples Statistics

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pretest	19,9231	39	8,04391	1,28806
	posttest	57,4872	39	11,02359	1,76519

Based on the analysis results displayed in Table 1, Paired Samples Statistics, a descriptive overview was obtained regarding students' conceptual understanding before and after the treatment was given. The data shows that the mean pretest score was 19.92, while the mean posttest score significantly increased to 57.48. This indicates improved students' conceptual understanding after the learning process was conducted. The number of research subjects (N) in both measurements is the same, which is 39 students, so the comparison of results can be considered consistent.

Furthermore, the standard deviation score for the pretest was 8.04, while it increased to 11.02 in the posttest. This increase in standard deviation indicates that after the treatment, the distribution of students' scores became more varied. In other words, although there was a general improvement in understanding, there were differences in achievement levels among students, with some achieving results significantly higher than others. The larger standard error mean in the posttest (1.77) compared to the pretest (1.29) also reinforces the indication of variation in students' achievements after the learning process. Overall, these results show that the instruction provided has significantly contributed to improving students' conceptual understanding. The significant average increase from pretest to posttest reflects the effectiveness of the learning process, although there are variations in individual achievements that need further attention in the evaluation of the learning process.

Table 2. Paired Samples Correlations

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	pretest & posttest	39	,315	,051

Based on the analysis results presented in Table 2, Paired Samples Correlations, a correlation coefficient of 0.315 was obtained with a significance (Sig.) of 0.051. Generally, the positive correlation value indicates a tendency of a unidirectional relationship between the pretest and posttest scores, although the strength is considered low. However, this relationship cannot be statistically significant since the significance value is greater than 0.05 (0.051 > 0.05).

This finding indicates that the increase in scores from pretest to posttest is not due to a direct relationship between initial and final scores, but rather is more attributed to the treatment or learning intervention provided. In other words, students who scored low on the pretest do not always remain in the same category after the posttest; thus, the post-learning

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achievement more reflects the learning process's impact than merely the students' initial condition.

This condition also indicates that the learning treatment provides relatively equal opportunities for all students to experience an improvement in conceptual understanding, without being significantly influenced by differences in their initial abilities. Thus, the applied learning can be regarded as effective in providing a positive impact on the students.

Table 3. Paired Samples Test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	pretest – posttest	-37,56410	11,41512	1,82788	-41,26446	-33,86375	-20,551	38	,000

Based on the analysis results presented in Table 3, Paired Samples Test, the mean difference between pretest and posttest is -37.56, with a standard deviation of 11.42 and a standard error mean of 1.83. The 95% confidence interval indicates that the score difference is within the range of -41.26 to -33.86, confirming the consistency of score improvement after the treatment. The testing decision is based on the significance value (Sig. 2-tailed). The analysis results show a value of 0.000, much smaller than the critical limit of 0.05 (0.000 < 0.05). Therefore, it can be statistically concluded that there is a significant difference between the pretest and posttest scores.

This finding confirms that the GeoGebra learning media applied in the Discovery Learning model significantly improve students' understanding of concepts. This means that using GeoGebra enhances student engagement in the learning process and significantly improves conceptual understanding compared to the initial conditions before the treatment. Therefore, these results support the effectiveness of integrating interactive technology in mathematics education to enhance student learning outcomes.

Table 4. Results of the Indicators

No	Pretest	Posttest
Indicator 1	125	301
Indicator 2	82	272
Indicator 3	71	216

Based on Table 4, the pretest and posttest results for each indicator of students' conceptual understanding can be seen. In Indicator 1, the pretest score of 125 increased to 301 in the posttest. For Indicator 2, the pretest score 82 significantly increased to 272 after instruction. Meanwhile, in Indicator 3, the pretest 71 rose to 216 in the posttest. The increase in scores for each indicator indicates that all aspects of students' conceptual understanding showed real development after the treatment. Indicator 1, which had the highest increase, signifies that this aspect received a more optimal understanding through the learning process.

Meanwhile, the increases in Indicator 2 and Indicator 3 are also significant, although with different absolute values, which shows that the effectiveness of learning has a positive impact evenly on various components of conceptual understanding. Overall, these findings affirm that learning using GeoGebra media in the Discovery Learning model can significantly enhance students' conceptual understanding, both on the easiest indicators and relatively more complex ones. This reinforces the evidence that interactive technology can help students internalize mathematical concepts more effectively.

The following are the responses of students chosen for further analysis that show significant changes in their understanding of mathematical concepts. Restating the concepts that have been learned.

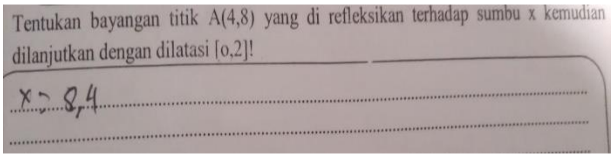

Figure 8. Pretest Restating the Concept

The next indicator of conceptual understanding is the ability to restate concepts that have been learned. In this indicator, the tested questions emphasize the material of transformation composition because this material involves transformations that are performed multiple times or repeatedly. In the Figure above, it can be seen that the questions provided to assess the understanding of the concept in the form of restating concepts that have been learned consist of two transformations, namely reflection and dilation. Subject 1's response shows that they could not articulate what they understood from the question and could not solve it. This indicates that the respondent could not restate the concept.

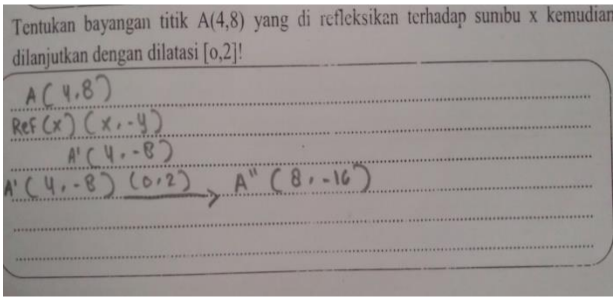

Figure 9. Posttest Restating the Concept

Based on the results of the posttest answers above, it can be seen that the student can restate the concepts that have been learned, namely the ability to determine the known information and solve the questions that were asked first. It is evident from the answers above that the student can write comprehensively, along with the symbols used in the composition of the transformation, and the answers given follow the problem-solving procedures. It can be stated that the respondent has understood the indicators of conceptual understanding by restating the concepts learned and presenting them in various forms of mathematical representation.

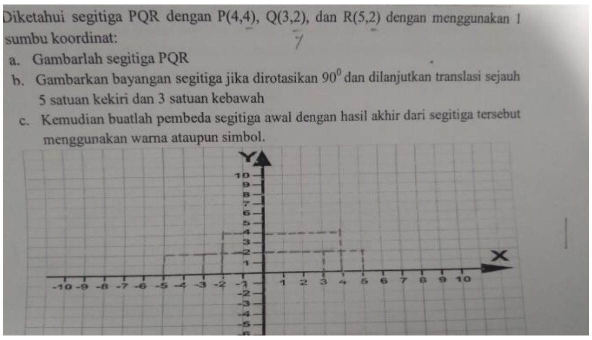

Figure 10. Pretest Presentation of Mathematical Representation Concepts

Based on the indicators of concept understanding, the presentation of concepts in the form of representation through graph drawing shows that the answers of subject 2 are unable to draw the graph and cannot differentiate the position of point x and point y, failing to produce the Figure requested by the question.

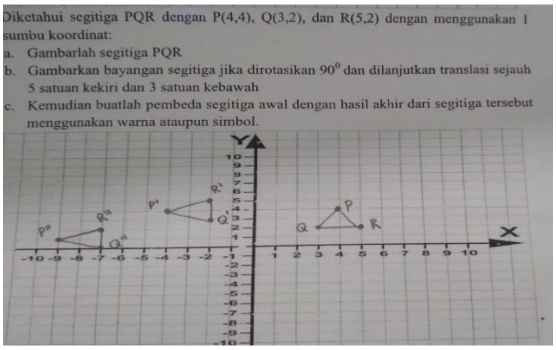

Figure 11. Posttest Presentation of Mathematical Representation Concepts

In Figure 11 above, it can be seen that the students can place point x and point y, thus forming the triangle as requested in the problem. The problem consists of several points, namely drawing a triangle with known points, and the students answered correctly regarding that triangle. In the next sub-question, the students were asked to illustrate the results of the requested transformation and to differentiate the final result of the triangle using symbols or colors. From these three sub-questions, the students drew and distinguished them using symbols. The initial Figure is triangle PQR, and the final Figure is P” Q” R”. Based on that answer, the students have presented the concept of mathematical representation in graphical form. Providing examples and non-examples of a concept.

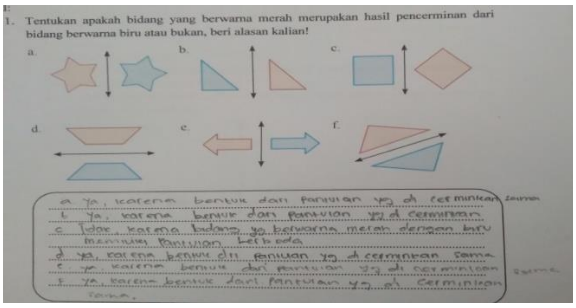

Figure 12. Pretest Indicator to Distinguish Between Examples and Non-Examples

In Figure 12 above, it can be seen that the students cannot distinguish which examples are of reflection and which are not. The response from subject 3 only looks at whether the shapes of the Figures are different, thus concluding that it is not a reflection, without considering the distance of each pair of corresponding corner points in the reflection.

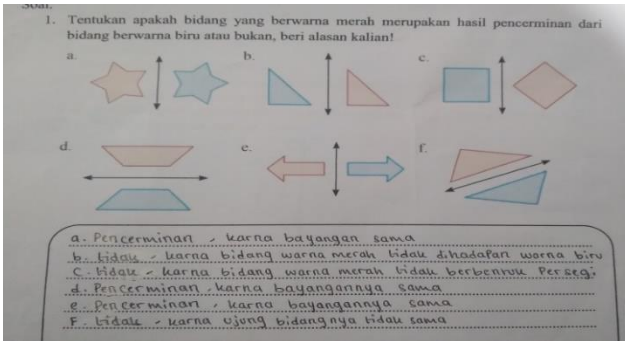

Figure 13. Posttest Indicator to Distinguish Between Examples and Non-examples

In Figure 13 above, after the students were given learning treatment using GeoGebra media through the Discovery Learning model, it is evident that there has been a change as the students have begun to understand mathematical concepts by providing reasons based on the position and distance of objects, thus the students now understand the concept of distinguishing between examples and non-examples using Figures.

As for the control class, the results obtained from the students' pretest-posttest scores are as follows:

Table 5. Paired Samples Statistics

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	18,1795	39	6,69592	1,07221
	Posttest	41,4103	39	9,44713	1,51275

Based on the analysis results in Table 5, a descriptive picture is obtained regarding the pretest and posttest scores of the students. The average (mean) pretest score is 18.18 with a standard deviation (Std. Deviation) of 6.70, indicating a moderate variation in scores among the 39 respondents. Meanwhile, the average posttest score increased to 41.41, with a standard deviation of 9.45, indicating an increase in score dispersion after the students underwent the learning process. The number of respondents in both measurements is the same, namely 39 students, so the comparison between pretest and posttest can be made consistently. The increase in the average score from pretest to posttest indicates significant progress in students' understanding of concepts after being given the learning treatment. In addition, the increase in the standard deviation on the posttest indicates variation in student achievements; some students show greater improvement than others. Thus, these descriptive results demonstrate that the provided instruction positively impacts students' conceptual understanding, while indicating individual differences in learning outcomes.

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Table 6. Paired Samples Correlations

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Pretest & Posttest	39	,023	,888

Table 6 presents the results of the paired correlation test between pretest and posttest scores. This analysis aims to determine the extent to which a relationship exists between the two measurements before and after treatment/intervention. The calculations obtained a correlation value of 0.023 with a significance value (Sig.) of 0.888. Based on statistical criteria, if Sig. < 0.05, then there is a significant relationship between pretest and posttest. However, in this study, the Sig. Value = 0.888 > 0.05, so it can be concluded that the pretest and posttest scores do not show a significant relationship. This indicates that the initial condition of the participants (pretest) does not influence the measurement results after treatment (posttest), so the changes that occur in the posttest are most likely influenced by the intervention or treatment provided, not by the initial condition of the participants.

Table 7. Paired Samples Test

Paired Samples Test									
Pair 1	Pretest - Posttest	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
		-23,23077	11,45118	1,83366	-26,94281	-19,51873	-12,669	38	,000

Table 7 presents the results of the Paired Samples Test used to determine whether there is a significant difference between the pretest and posttest scores in the control class. This analysis aims to assess the effectiveness of the learning provided on the changes in participants' scores. From the analysis results, the average difference (Mean) obtained is -23.23077 with a standard deviation of 11.45118 and a standard error mean of 1.83366. The 95% confidence interval shows a lower limit of -26.94281 and an upper limit of -19.51873, confirming that the changes in pretest and posttest scores fall within a negative range, which indicates an increase in scores from pretest to posttest. Furthermore, the t-test results yield a t value of -12.669 with degrees of freedom (df) = 38 and a significance value (Sig. 2-tailed) of 0.000. Since the Sig. Value is < 0.05; it can be concluded that there is a significant difference between the pretest and posttest scores in the control class. This indicates that the learning provided can positively impact the improvement of participants' scores, even though the class is a control group, and this change did not occur by chance.

3.2. Discussion

The research results show that implementing the Discovery Learning model assisted by GeoGebra significantly improves students' understanding of mathematical concepts. These findings align with several previous studies that emphasize the effectiveness of using interactive media and inquiry approaches in mathematics learning [16].

In the Stimulation stage, the teacher presents real phenomena or events relevant to the material. The goal of this stage is to stimulate curiosity, motivation to learn, and the initial engagement of students. This supports the findings of Anggraini [17] which state that early stimulation through phenomena that are close to students' experiences can enhance active participation and enthusiasm for learning. In this study, observations in Figure 2 show that students actively ask questions and build initial hypotheses related to the concepts to be learned, indicating a high level of cognitive and affective engagement.

The Problem Statement stage emphasizes developing critical and analytical thinking skills through problem identification and hypothesis formulation. The findings of this research support the study [18], which shows that students involved in formulating problems and hypotheses can develop scientific thinking and assess issues from various perspectives. Observation of Figure 3 shows that students actively interact, express initial conjectures, and propose alternative solutions, proving that this stage is effective in honing critical thinking skills.

The Data Collection and Data Processing stage emphasizes systematic data collection and analysis. Students are guided to work meticulously, objectively, and based on evidence, which supports the development of logical and analytical thinking skills [11]. Based on figures 4 and 5, students can record information well and process it into rational solutions, showing an increased capacity for scientific thinking. This process also strengthens data representation skills, essential in modern mathematics learning.

In the verification stage, GeoGebra allows students to visualize mathematical concepts, check the relationships between data, and ensure the correctness of hypotheses. This result aligns with [19], which found that GeoGebra enhances students' mathematical representation skills and answer validation. Observations in Figure 6 show that students can verify answers interactively, combining critical thinking skills and technology, making the learning process more valid and meaningful.

The Generalization stage is the peak of the inquiry series, where students draw conclusions and formulate general principles from the learning process. This supports the findings of Septian [20], which state that generalization helps students internalize concepts to be applied in various contexts. Figure 7 shows that students can conclude systematically and logically in this study, proving that the learning objectives have been achieved.

Quantitative analysis reinforces qualitative findings. Based on Table 1, the average pretest score of 19.92 increased to 57.48 on the posttest, with the standard deviation rising from 8.04 to 11.02. This indicates a significant improvement in conceptual understanding despite variations in student achievement. The pretest-posttest correlation (Table 2) is positive but not significant (r = 0.315; Sig. 0.051), indicating that the improvement in scores is not solely influenced by students' initial abilities, but is a direct effect of the learning treatment. The paired t-test results (Table 3) are significant (Sig. 0.000), confirming that GeoGebra-based learning effectively enhances conceptual understanding.

The analysis of the concept understanding indicators shows consistent improvement. In the indicator of restating concepts, students who initially could not write the transformation procedures can now solve the problems completely (Figures 8-9). In the indicator of presenting concepts in mathematical representation, students successfully drew the transformation graph and distinguished between the starting and ending points and the appropriate symbolism (Figures 10-11). The indicator of distinguishing examples from non-examples of a concept also shows improvement, with students able to provide reasons based on the position and distance of objects (Figures 12-13). These findings align with [21], which shows that using GeoGebra strengthens conceptual understanding through interactive visual representations.

The results in the control class showed an increase from the pretest average of 18.18 to a posttest of 41.41, but still lower compared to the experimental class. The pretest-posttest correlation was not significant (r = 0.023; Sig. 0.888), indicating that the initial conditions of the students did not affect the posttest results. The paired t-test was significant (Sig. 0.000), indicating an improvement in understanding, but the effect was less optimal compared to the experimental class. This is consistent with Utam et al. [22], who found that integrating interactive media like GeoGebra improves conceptual understanding more than conventional methods.

Overall, the findings of this study affirm that GeoGebra-assisted Discovery Learning significantly enhances mathematical concept understanding. Improvements were observed across all concept indicators, both simple and complex, indicating that this approach effectively develops students' critical thinking skills, mathematical representation abilities, and data analysis. Integrating interactive technology and inquiry-based learning provides a more meaningful and applicable learning experience while accommodating differences in students' initial abilities, uniformly improving learning outcomes.

Several previous studies discuss mathematics learning with a different focus from this research, so the results are inconsistent with the findings obtained. For example, a study by Fatmawati et al. [23] explored the use of Traditional Lecture methods to improve the basic arithmetic skills of elementary school students. Although the method showed an increase in posttest scores, the focus of the research on basic arithmetic skills differs from this study, which emphasizes conceptual understanding through Discovery Learning assisted by GeoGebra. This result indicates that the improvement in conceptual understanding gained from interactive learning cannot be fully compared to conventional lecture-based learning, due to the differences in approach and the cognitive levels developed.

Other research by [24] researched the influence of using video learning media on student motivation in science subjects. Their findings show that student motivation increases, but the improvement in understanding mathematical concepts was not analyzed. Thus, although student motivation can increase through interactive media, it does not always imply increased critical thinking skills and mathematical representation, as demonstrated in this study. This emphasizes that motivation alone is insufficient without active engagement and systematic data analysis, key characteristics of the Discovery Learning model.

In addition, research by Afhami [25] investigated the effect of project-based learning on the visual arts. This research focuses on students' creative and aesthetic abilities, rather than the development of mathematical concepts or procedures. Although there are similarities in the exploratory approach, the context and indicators of learning outcomes differ. The findings of this research show that while students in creative projects can demonstrate improvements in specific skills, these cannot be directly applied to measure understanding of abstract and logical mathematical concepts.

By comparing the findings from these irrelevant journals, it can be concluded that the results of previous studies do not directly support or oppose the effectiveness of GeoGebra-assisted Discovery Learning. This indicates that the success of interactive learning in mathematics greatly depends on the compatibility of the methods, media, and indicators used. In other words, although some other methods may enhance motivation or specific skills, their effectiveness in improving mathematical concept understanding still needs to be explicitly tested according to the learning context.

Overall, this comparison emphasizes that previous irrelevant research provides an understanding that the effectiveness of learning is highly contextual. Approaches that are successful in other fields of study or different cognitive aspects may not necessarily be effective in learning mathematical concepts that require representation, data analysis, and logical and systematic problem solving.

4. CONCLUSION

Based on the research findings, it can be concluded that implementing the Discovery Learning model assisted by LKPD and GeoGebra has been proven effective in enhancing students' understanding of mathematical concepts. This is evident from the statistical test results showing a significant difference between the pretest and posttest scores in the experimental class. GeoGebra significantly contributes to visualizing abstract concepts into more concrete forms, allowing students to restate concepts, present mathematical representations, and distinguish between examples and non-examples of a concept more effectively. These findings have important implications for teaching practices in schools. For teachers, the results of this research can be an alternative, innovative strategy in teaching abstract materials, particularly in geometric transformations. For students, using GeoGebra enhances critical thinking skills and motivates them to be more active in the learning process. Meanwhile, for schools, the results of this research can encourage policies for integrating digital learning media into the mathematics curriculum.

Nevertheless, this research has several limitations. First, the sample size is limited, so the results cannot be widely generalized. Second, the study only focuses on one topic, geometric transformations, so the effectiveness of GeoGebra in other mathematics materials is not yet known. Third, external factors such as differences in motivation, academic background, and students' learning styles cannot be fully controlled. Based on these limitations, further research is suggested to involve more samples from various schools to generalize the results. Further research could also examine the effectiveness of GeoGebra on other mathematics topics, such as algebra or calculus, and try to combine it with other learning models, for example, Problem-Based Learning or Project-Based Learning. Furthermore, longitudinal research can be conducted to observe the long-term impact of using GeoGebra on students' learning outcomes and higher-order thinking skills.

REFERENCES

[1] C. Rooney, "How am I using inquiry-based learning to improve my practice and to encourage higher order thinking among my students," *Journal of Social Sciences*, vol. 6, no. 2, p. 252–255, 2024.

[2] W. Wahyudi, "Penerapan model pembelajaran Discovery Learning berbantuan GeoGebra pada materi program linear," *Silogisme: Jurnal Pendidikan Matematika,* vol. 16, no. 2, p. 1–10, 2022.

[3] Maulani, F. Indah and L. Zanthy, "Analisis Kesulitan Siswa Dalam Menyelesaikan Soal Materi Transformasi Geometri," *Gammath : Jurnal IlMIAh Program Studi Pendidikan Matematika,* vol. 5, no. 1, p. 16–25, 2022.

[4] S. Sudrajat, "Pemahaman Relasional dan Instrumental: Bagaimana Pengaruhnya dalam Pembelajaran Matematika Ditinjau Dari Pemecahan Masalah Matematis?," *ELIPS: Jurnal Pendidikan Matematika,* vol. 3, p. 45–52, 2022.

[5] P. Nguyen and P. Nuangchalerm, "Learning outcomes of project-based and inquiry-based learning activities," *Journal of Social Sciences,* vol. 6, no. 2, p. 252–255, 2020.

[6] B. Siagian, "Application of discovery learning model for solving system of linear equations using GeoGebra," *International Journal of Applied Engineering Research,* vol. 12, no. 1, p. 9195–9198, 2022.

[7] F. Siahaan, "Application of discovery learning model for solving system of linear equations using GeoGebra," *International Journal of Applied Engineering Research,* vol. 12, no. 1, p. 9195–9198, 2022.

[8] M. Nasution and I. Dewi, "Pengaruh Model Discovery Learning Berbantuan Geogebra terhadap Kemampuan Pemahaman Konsep Matematis Siswa di SMP Negeri 3 Tanjung Morawa," *Journal on Education,* vol. 6, no. 2, pp. 13514-13526, 2024.

[9] Atmaja, "Koneksi Indikator Pemahaman Konsep Matematika Dan Keterampilan Metakognisi," *Nusantara: Jurnal Ilmu Pengetahuan Sosial,* vol. 8, no. 7, p. 2048–2056, 2021.

[10] K. Adriana, N. Nst and Reflina, "Analisis Kemampuan Berpikir Kreatif Matematis Menggunakan Media Pembelajaran Interaktif Berbantuan Geogebra Pada Fungsi Kuadrat," *Relevan : Jurnal Pendidikan Matematika,* vol. 32, no. 1, p. 186–194, 2023.

[11] A. Karomah, M. Lubis and L. Afri, "Pengaruh Penggunaan Aplikasi Geogebra Terhadap Pk Dan Kvs Pada Siswa Mtsn Binjai," *Relevan : Jurnal Pendidikan Matematika,* vol. 3, no. 1, p. 6–11, 2023.

[12] J. Creswell, Desain Penelitian: Pendekatan Metode Kualitatif, Kuantitatif, dan Campuran (edisi ke-4), Thousand Oaks: CA: Publikasi Sage, 2020.

[13] Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, Dan R&D, Bandung: CV. Alfabeta, 2022.

[14] L. J. Moleong, Metode Penelitian Kualitaif, Bandung: PT. Remaja Rosdakarya, 2000.

[15] H. Miles and Saldaña, Qualitative Data Analysis: A Methods Sourcebook, New York: SAGE Publications, 2024.

[16] K. Wasi, "Pengembangan Media Matematika Interaktif Berbantuan Software Geogebra Pada Materi Transformasi Geometri Kelas XI SMA," *Jurnal IlMIAh Multi Disiplin Indonesia,* vol. 12, no. 1, p. 1897–1906, 2022.

[17] Anggraini, "Analisis Pemahaman Konsep Matematika Siswa Pada Materi Transformasi Geometri Berdasarkan Teori Apos (Aksi, Proses, Objek, Skema)," *PENGAJARAN : Jurnal Inovasi Keguruan Dan Ilmu Pendidikan,* vol. 4, no. 4, pp. 267-278, 2024.

[18] I. Nurfitria and Yerizon, "The Effect of the GeoGebra-Assisted Discovery Learning Model on Mathematical Communication Abilities," *Asian Journal of Education and Social Studies,* vol. 51, no. 8, p. 699–708, 2025.

[19] A. Martínez-Zarzuelo, Á. Nolla, T. Recio, P. Tolmos, B. Ariño-Morera and A. Gallardo, "An Experience with Pre-Service Teachers, Using GeoGebra Discovery Automated Reasoning Tools for Outdoor Mathematics," *Education Sciences,* vol. 15, no. 6, pp. 782-800, 2025.

[20] A. Septian, M. L. Fahrisyal and N. Jusniani, "Pengembangan GeoGebra Classroom Pada Materi Transformasi Geometri," *Prisma,* vol. 5, no. 1, pp. 504-520, 2023.

[21] M. Aminudin, M. A. Basir, D. Wijayanti, H. R. Maharani, I. Kusmaryono and B. Saputro, "Pelatihan Penggunaan Geogebra Classroom untuk Mengoptimalkan Pembelajaran Matematika," *Jurnal ABDINUS : Jurnal Pengabdian Nusantara,* vol. 4, no. 2, p. 417–428, 2021.

[22] W. B. Utami, B. M. Sena, F. Isnani, Aulia, M. Haryono and Iskandar, "The Effect of Discovery Learning Supported by GeoGebra Application and Contextual Teaching Learning towards Mathematical Problem Solving Ability," *Jurnal Pendidikan MIPA,* vol. 20, no. 2, p. 46–53, 2024.

[23] Fatmawati. and Yahfizham, "Systematic Literature Review: Pemanfaatan Aplikasi Geogebra Pada Materi Transformasi Geometri," *IJMSE: International Journal of Mathematics and Science Education,* vol. 2, no. 1, pp. 1-11, 2024.

[24] A. Afhami, "Aplikasi Geogebra Classic Terhadap Pemahaman Konsep Matematika Siswa Pada Materi Transformasi Geometri," *Plusminus: Jurnal Pendidikan Matematika*, vol. 21, no. 1, pp. 449-460, 2022.

[25] Khasinah, "Discovery Learning: Definisi, Sintaksis, Keunggulan dan Kelemahan," *MUDARRISUNA: Media Kaji Pendidik Agama Islam*, vol. 11, no. 3, pp. 402-413, 2023.