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Evaluation of geometry skills: Integrating logic and drawing indicators through GeoGebra-based learning

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ABSTRACT

The problem in this study is to evaluate the improvement of students' geometry skills using the GeoGebra application by focusing on two key indicators: logical thinking and drawing skills. This study employs both quantitative and qualitative methods. In the first stage, quantitative data were collected through pretests and posttests to measure student geometry skill changes. In the second stage, qualitative methods were used to explore and validate the quantitative findings through geometry skill tasks and interviews. The research subjects were second-semester mathematics education students at Bina Bangsa University, selected using purposive sampling. The findings reveal that students who engaged in geometry learning with GeoGebra experienced significant improvement in both logical reasoning and geometric drawing skills. Students became better at visualizing geometric problems, constructing geometric figures accurately, and connecting visual information to logical reasoning processes. GeoGebra improved students' ability to identify patterns, perform deductions, draw conclusions, and visually communicate geometric ideas. It is recommended that GeoGebra be complemented with mathematical writing and drawing activities in geometry instruction to strengthen further the logical and visual dimensions of students' geometric thinking.

INTRODUCTION

Basic geometry skills are a crucial foundation in mathematics education, contributing to academic development and everyday problem-solving. These skills support geometric thinking, critical reasoning, and analytical abilities. Research by İbili et al. (2020) emphasized that mastering basic geometry skills enhances students' geometric thinking. Meanwhile, Andini et al. (2018) demonstrated that such mastery is essential for achieving informal deductive thinking as described in Van Hiele's thinking model.

Geometric skills refer to the capacity to comprehend and utilize basic principles of geometry. Hoffer (1981) states these skills include visual, verbal, drawing, logical, and applied aspects. Jebur (2020) confirms this categorization by identifying five key indicators of geometry skills. Among these, logical and drawing skills are particularly significant, as they are closely linked to the development of geometric thinking. Drawing skills help students visually represent geometric objects, while logical skills support structured reasoning and problem-solving. These two abilities complement each other in building a deep understanding of geometry from visual representation to abstract reasoning.

In VanHiele (1959) theoretical model, drawing skills are relevant at the visualization and analysis levels, while logical reasoning becomes critical at the informal and formal deduction levels.

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Hoffer (1981) also emphasized that drawing is not merely a representational tool but an integral part of geometric reasoning. However, the literature lacks detailed discussions on the interplay between logical and drawing skills in supporting geometric thinking. Significantly few studies have addressed how these two aspects function together in helping students understand and solve geometric problems (Hamidah et al., 2025). In reality, many students, including those at the university level, still exhibit low levels of geometric thinking. Şefik et al. (2018) found that only 49% of students reached level 1 (analysis), and 54% reached level 3 (abstraction) in the Van Hiele model. This highlights a significant gap in the mastery of geometry skills. A contributing factor is the reliance on conventional teaching approaches, which frequently do not actively involve students. Paramitha et al. (2024) argue that conventional instruction makes understanding geometric concepts difficult. Jelatu et al. (2018) further state that purely textual geometry instruction lacks connection to real-world contexts, making concepts more challenging to grasp. Alghadari et al. (2020) also point out that students often understand concepts in isolation but struggle to connect them meaningfully.

Many studies recommend using educational technology, such as the Geogebra application, to address these challenges. Khalil et al. (2019) propose that geometry learning should be interactive and tailored to students' needs. Geogebra is an interactive geometry tool that enables students to manipulate geometric objects visually, enhancing their understanding of abstract concepts (Juandi et al., 2021; Septian et al., 2020; Zhang et al., 2023). Integrating technology has also proven effective in enhancing student participation in learning activities (Kee et al., 2023; Ng et al., 2023).

Various research findings have highlighted Geogebra's effectiveness in improving conceptual understanding and increasing student participation (Celen, 2020; Yohannes & Chen, 2023; Zulnaidi et al., 2020). However, there is a lack of research that analyzes explicitly how students use their logical and drawing skills when solving geometry problems after learning with Geogebra. Logical skills are crucial for constructing step-by-step solutions and forming abstract representations of geometric objects, while drawing enables learners to explore and test ideas visually. Analyzing these aspects can provide valuable insights for identifying optimal strategies to enhance students' geometry skills.

This research examines students' geometry abilities following instruction using the Geogebra application, focusing primarily on logical and drawing indicators. This study intends to investigate students' geometric skills after being taught with the Geogebra application, and to identify common errors students make when solving geometry problems. The following questions guide this research: 1) How does the improvement of geometry skills compare between students who use Geogebra and those who do not? 2) What are students' geometry skills after learning with Geogebra, particularly in logical reasoning and drawing?

METHODS

This study adopts a mixed-methods strategy involving qualitative and quantitative techniques, particularly in logical reasoning and drawing, to better understand students' geometry skills. The study is carried out in two distinct phases. At the beginning of the process, quantitative methods are used to measure the improvement in geometry skills after using Geogebra in learning. At the study's second phase, qualitative methods are used to explore in more depth how students apply logical and drawing skills when solving geometry problems.

Research framework and constructs

This study is based on the framework of geometry skills as defined by Jebur (2020), which includes five key indicators: visual, verbal, drawing, logical, and applied skills. This study focuses on the logical and drawing components, which are theoretically linked to geometric thinking development as outlined in Van Hiele's model (1959). Logical skills in this context refer to students' ability to use deductive or inductive reasoning in solving geometric problems. In contrast, drawing skills refer to students' ability to construct and represent geometric shapes to support problem-solving.

The instrumentation design is aligned with this framework. The test instrument consists of descriptive items developed based on the logical and drawing indicators. Content experts validated and adjusted the items to ensure alignment with the research objectives and geometry learning outcomes.

Participants and sampling

The participants were selected using purposive sampling from two classes of second-semester mathematics education students at Bina Bangsa University. It was taken into account that the students were in their second semester when making the selection, and were about to take the Geometry course for the first time, making them suitable for assessing the initial impact of using Geogebra. A total of 23 students participated in the quantitative stage, while three students were selected for qualitative interviews, representing high, medium, and low performance based on post-test results.

Data Collection Instruments

Data collection in this study was carried out using two principal instruments. The first was a Geometry Skills Test consisting of five essay questions, each designed to represent one of the five geometry skill indicators: visual, verbal, logical reasoning, drawing, and applied skills. Although the test instrument was developed to cover all five indicators, this study specifically focused on analyzing two indicators, logical reasoning and drawing skills. These two were selected because they are most directly supported by the features of the GeoGebra application and align with the specific objectives of this study, which aimed to explore how visual tools influence students' reasoning and representational abilities in geometry.

The test development process followed several stages to ensure the quality of the instrument. A test blueprint was created based on theoretical frameworks of geometry skills, followed by the development of item drafts. Three mathematics education experts reviewed these to assess content validity, and the items were revised accordingly. The final version of the test was pilot-tested with a group of students outside the research sample. The results were analyzed to evaluate item clarity, discrimination, and internal consistency, thus ensuring the validity and reliability of the instrument before it was used in the actual study.

The second instrument was a semi-structured interview guide, designed to collect qualitative data on students' experiences with GeoGebra-based learning, their strategies for solving geometry problems, and their specific challenges related to logical reasoning and drawing. Experts also validated the interview questions to ensure clarity and alignment with the study's goals.

Data collection procedure

The data collection procedure involved several stages. A pretest was administered to determine students' initial geometry skills. This was followed by a learning intervention consisting of four sessions on triangle and quadrilateral topics, using the GeoGebra application as the primary instructional tool. After the intervention, a posttest was conducted using the same instrument to assess student geometry skills improvement. Three students, selected based on their exam performance and interest in participating, were interviewed individually the week after. The interviews served to validate and expand upon the quantitative findings through more profound insights into students' thought processes and learning experiences.

Data analysis technique

Quantitative data analysis began with normality and homogeneity tests to confirm the suitability of the data for parametric analysis. A paired sample t-test was used to measure the significance of improvement in students' geometry skills between the pretest and posttest. A percentage analysis was also conducted to evaluate student performance on the two targeted indicators: logical reasoning and drawing skills.

For qualitative data, the analysis followed Miles and Huberman's interactive model, which includes data reduction, data display, and conclusion drawing (Creswell, 2015). To ensure the validity and consistency of the findings, a triangulation technique was applied by comparing students' written test answers, interview responses, and other relevant student work. This approach strengthened the interpretation of the results by drawing on multiple data sources.

Table 1
Scoring rubric for basic geometry skills test

Score	Criteria
0	A situation where the problem is completely misunderstood, meaning the problem is not understood, or no action is taken.
1	A situation where the problem is understood (the question is expressed with an algebraic version of the problem written down, or brief notes are taken about this expression, graphs are drawn, tables are created, and the expression/truth of the argument/proposition given is tested with examples).
2	A situation where what is asked in the question is understood (precisely understanding what needs to be proven, determining the proof method, making/realizing the logical steps given for this, but unable to conclude the proof fully, or there are deficiencies/errors in some stages of the evidence).
3	A situation where the proof is completed correctly.

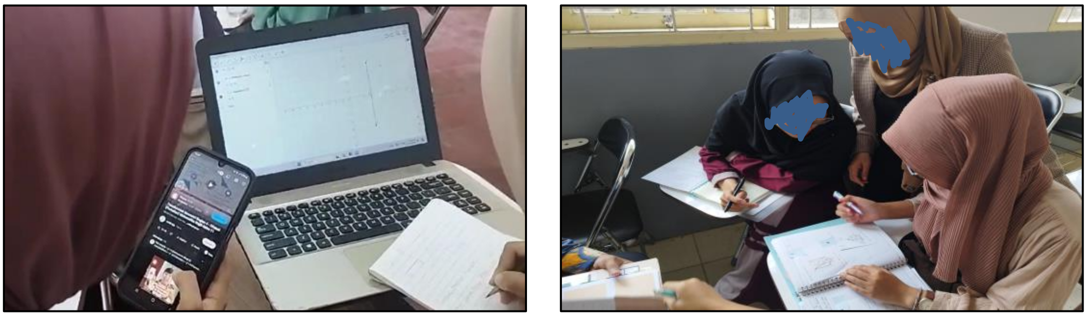


Figure 1. Examples of student activities while using GeoGebra

Triangulation and integration

This study uses methodological triangulation, combining test results and interviews to provide an in-depth understanding of students' logical and drawing skills. According to Rukin (2019), triangulation helps confirm findings from multiple sources. Triangulation was used in this research to evaluate how students employed logical steps and drawing representations when solving geometry problems, and how these two aspects contributed to their geometric thinking. The scoring of students' work in solving geometry skills problems refers to the rubric (Demircioğlu & Hatip, 2022) as presented in Table 1.

FINDINGS

Figure 1 shows the students actively visually manipulated geometric objects through the application during the GeoGebra-based learning process. They drew various plane shapes, observed geometric properties, and explored geometric concepts more interactively and dynamically. This activity enhanced conceptual understanding and promoted logical reasoning skills and drawing abilities. The following figure shows examples of student activities while using GeoGebra to complete geometry tasks.

The average difference test of geometry skills

Students' geometry skills before and after learning

The results of students' geometry skills tests, administered before and following the learning period for experiment and control class, are outlined in Table 2. It is ndicates that the experimental class achieved a higher average score in geometry skills compared to the control class. Both groups improved geometry proficiency; however, the experimental class demonstrated greater progress. According to the N-Gain classification, the experimental class falls into the 'effective' category with an N-Gain score of 0.78 (78%), while the control class achieved an N-Gain score of 0.57 (57%). These results suggest that the experimental class experienced a more substantial improvement than the control class.

Table 2
Descriptive analysis of geometry skills test scores

	Experiment			Control		
	Pretest	Posttest	Gain	Pretest	Posttest	Gain
Maximum value	8	95	0,95	8	70	0,68
Minimum value	0	52	0,52	0	55	0,50
Standard deviation	2,68	14,95	0,15	3,16	4,65	0,05
Average	2,96	79,04	0,78	4,61	59,96	0,57

Table 3
Paired samples t-test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	N-gain Eksperimen – N-gain Kontrol	-13.077	11.996	3.327	-20.326	-5.828	-3.930	45	0.000

Normality and homogeneity tests

The results of the normality test show that the significance values for the N-Gain data of the experimental and control classes were 0.65 and 0.25, respectively, both exceeding 0.05. This indicates that the data in both groups are normally distributed. In addition, the homogeneity test using SPSS yielded a significance value of 0.88, which is also greater than 0.05, indicating that the data from both classes are homogeneous.

Average difference test results

Given that the data are normally distributed and homogeneous, the t-test was utilized to test the hypothesis of mean difference. The SPSS output is presented in Table 3. According to the t-test results in the Table 3, the significance value (Sig.) is 0.000, below the 0.05 threshold. This indicates that the alternative hypothesis (Ha) is accepted, meaning there is a significant difference in the improvement of geometry skills between students in the experimental and control groups. Additionally, the average N-Gain for the experimental class is higher than that of the control class. These findings suggest that geometry learning using the Geogebra application has a more positive impact on enhancing students' geometry skills than learning without the application.

Evaluating students' geometry skills

The effectiveness of learning geometry through the Geogebra application in improving students' skills has been demonstrated. The subsequent analysis focuses on students' geometry skills, drawing on test results and interview data.

Data reduction

Based on posttest data, students' geometry skills were grouped into high, medium, and low categories. In addition, one student from each category was chosen as a representative. An interval-based representation of the experimental class group's posttest score distribution is used. The distribution of scores is divided into three groups: high, medium, and low, based on the experimental class students' geometry competence scores (Rahmawati, 2020). The outcomes of data processing to categorize student scores are: 1) $80 \leq$ score ≤ 100 (High Category); 2) $60 \leq$ score < 80 (Medium Category); and 3) $0 \leq$ score < 60 (Low Category). Based on this classification, the posttest score information for the two groups is displayed in Table 4.

As shown in Table 4, over half of the students are categorized as having high-level geometry skills. Nevertheless, nine students were identified as needing further analysis to better support the development of their geometry abilities. To gain comprehensive insights, analysis will be conducted across all skill categories. One student from each category will be selected for in-depth analysis of their work and follow-up interviews. Three students, each representing a different geometry skill

Table 4
Students' geometry skills category

Category	Number of Students	
	F	%
High	14	60,87
Medium	3	13,04
Low	6	26,09
Sum	23	100

Table 5
Number of Students Who Made Mistakes Based on the Newman Procedure

	Number of Students Doing Kesalahan (n=23)					Sum	Percentage
	Number 1 Visual	Number 2 Verbal	Number 3 Drawing	Number 4 Logic	Number 5 Applied		
Reading	2	0	5	3	0	10	8,69
Comprehension	5	2	6	5	0	18	15,65
Transformation	6	6	6	7	2	27	23,48
Process skill	6	9	12	17	3	47	40,87
Encoding	6	9	21	23	4	63	54,78
Sum	25	26	50	55	9		

category, will have their problem-solving work analyzed. These selected students will also participate in interviews to provide additional information regarding their learning process and performance. Five types of errors are outlined in accordance with Newman's procedures, namely (1) reading, (2) comprehension, (3) transformation, (4) process skill, and (5) encoding (Noutsara et al., 2021; Zinc, 2020; Suseelan et al., 2022). This category is a foundation for analyzing students' mistakes in solving geometry-related problems.

Data Presentation

Table 5 presents an analysis of the errors the 23 experimental class students made, categorized using Newman's procedure. Table 5 demonstrates that, with 55 errors, students make the most mistakes on question 4. Based on the error categories, all 23 students were found to have made mistakes in the encoding category. A deeper analysis also reveals many errors in process skills, with 17 out of 23 students experiencing difficulties in this area. Process skill errors refer to applying the correct steps to solve problems. This indicates that students who struggle with process skills will likely produce incorrect final representations of their answers. A similar pattern is observed with other types of errors. For instance, transformation errors, mistakes in converting mathematical information into different forms, can lead to subsequent errors in both process skills and encoding.

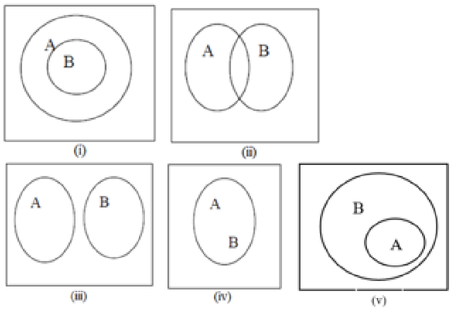
Interestingly, the distribution of student errors based on Newman's procedure follows a sequential pattern: reading errors are the least frequent, followed by errors in comprehension, transformation, and process skills, with encoding errors being the most prevalent. This pattern suggests that when students begin making mistakes at the reading stage, they are more likely to encounter difficulties in the subsequent stages. This occurs because an inability to accurately read key information or understand the question makes it difficult for students to progress through the problem-solving process and produce a correct final answer.

Question number 4 is the question with the most student-solving errors. This problem is a question of logic indicator geometry skills, which means that, in general, students still have difficulty using logical and deductive reasoning in understanding, analyzing, and solving geometry problems, so they apply the wrong steps to solve them and write the incorrect final result. Furthermore, question number 3 is also a question that has many mistakes in its completion by students. This question is about geometric thinking skills of drawing indicators; it indicates that students still struggle to use geometric drawings in general or perform geometric constructions from various perspectives as a communication tool to explain geometric concepts or answer questions related to geometry.

Table 6
Students' errors based on the Newman procedure

Geometry Skills Category	Student Errors Based on the Newman Procedure				
	Question Number 1 Visual	Question Number 2 Verbal	Question Number 3 Drawing	Question Number 4 Logic	Question Number 5 Applied
High	true	true	Inappropriate:encoding	Inappropriate: process skill, and encoding	true
Medium	true	Inappropriat: process skill, and encoding	Inappropriate:process skill, and encoding	Inappropriate: process skill, and encoding	true
Low	Inappropriate: comprehensio, transformation, process skill, and encoding	Inappropriat: transformation, process skill, and encoding	Inappropriate: comprehension, transformation, process skill, and encoding	Inappropriate: transformation, process skill, and encoding	Inappropriate: process skill, and encoding

Question:
Recall the Venn diagram on the set material.



1. If A : Parallelogram properties
   B : properties of rectangles
   So, which form of Venn diagram states the relationship A and B? Explain.
2. If A : the properties of the rhombus
   B : parallelogram properties
   So, which form of Venn diagram states the relationship A and B? Explain.

Figure 2. Logic indicator geometry skills questions

Table 6 describes the errors made by experimental class students, selected randomly from each geometry skill category, as analyzed using Newman's procedure. Table 6 summarizes student errors categorized into high, medium, and low levels. It can be observed that students in the low geometry skills category tend to make numerous mistakes on nearly all question items. Overall, students view items 3 and 4 as presenting a higher difficulty level, whereas item 5 is generally considered easy.

Student's answer analysis on the logical indicators

The analysis of the students works on the geometry skill problems of logic and drawing indicators was reviewed from the geometry skill category, namely high, medium, and low. The first analysis is question number 4, a fundamental geometric skills question with logical indicators as presented in Figure 2.

Analysis of high geometry skills category

Figure 3 displays the excerpt of a high category student's answer in question number 4, the geometric skills question with logical indicators. In Figure 3, students categorized under the high

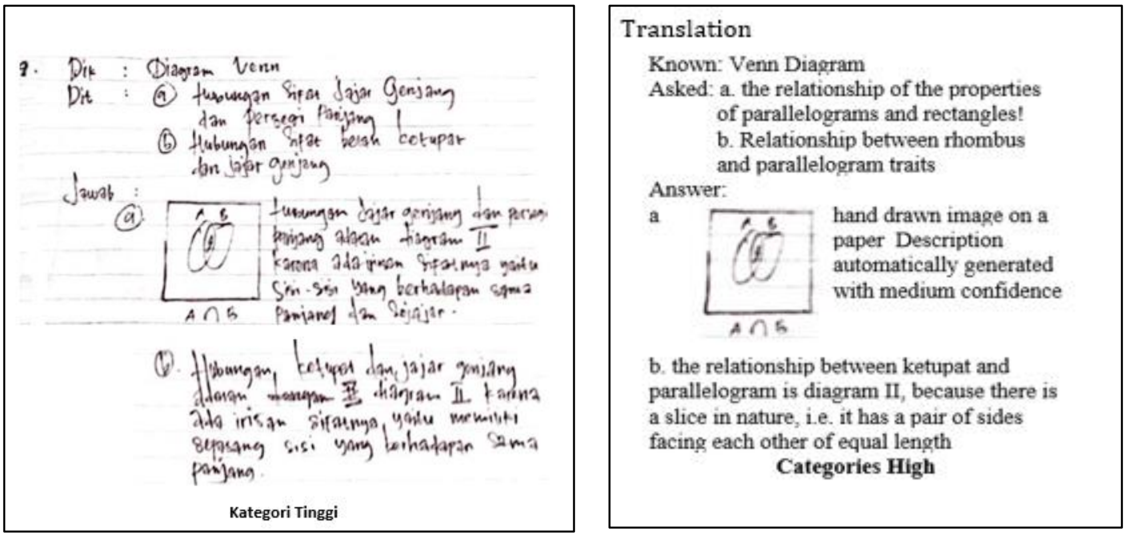


Figure 3. High category student answers on question with logic indicators

level of geometry skills demonstrate a generally structured problem-solving process, such as presenting information in a sequence, starting from identifying what is known and being asked, and proceeding to solve the problem. However, analysis of responses to question number 4, which measures logical reasoning skills, reveals that some students still experience difficulties in applying deductive logic when analyzing geometric relationships. Specifically, one standard error lies in their inability to interpret and relate plane shapes' properties. In this case, students failed to describe the characteristics of shapes such as rectangles and rhombuses and did not construct a proper Venn diagram to visualize their relationships. This indicates a gap in understanding that rectangles and rhombuses are exceptional cases of parallelograms. A rectangle, for example, is a type of parallelogram in which all angles are 90 degrees, while a rhombus is a parallelogram where all sides are of equal length. Although all rhombi and rectangles are parallelograms, not all parallelograms are rectangles or rhombi due to specific defining features. Misunderstanding this hierarchy reflects incomplete conceptual knowledge.

The encoding error identified in this group refers to incorrect conclusions drawn by students. One student stated, *"I feel that my answer is correct. However, there is a lack of confidence because I should have written down the properties of the parallelogram and the rectangle one by one so that the relationship is visible. Still, I forgot to remember the properties of the plane shape."* This reflects a partial understanding that students can logically reason and recognize similarities between properties, but their ability to recall and articulate specific characteristics is still limited.

Another student admitted, *"I need to relearn the definition and properties of each plane shape because I feel like I have forgotten a lot."* This suggests that even high-performing students require more practice recalling, writing, and organizing geometric properties. This skill can be strengthened by encouraging students to write down regularly and group shape properties, followed by making logical conclusions based on these groupings. Writing activities, as supported by Santos and Barbosa, (2023), and Žakelj and Klancar (2022), significantly influence the improvement of students' geometric concept mastery, structure mathematical reasoning, and build connections between concepts. Students can better visualize, describe, and justify geometric ideas through writing while reinforcing their comprehension through verbal and visual representations.

Analysis of medium geometry skills category

Figure 4 shows the excerpt of a medium category student's answer in question number 4. In Figure 4, students in the medium geometry skill category possess a basic understanding of geometric concepts, they still experience substantial difficulty performing tasks requiring deductive and logical reasoning. In question number 4, which assesses the ability to analyze and establish relationships

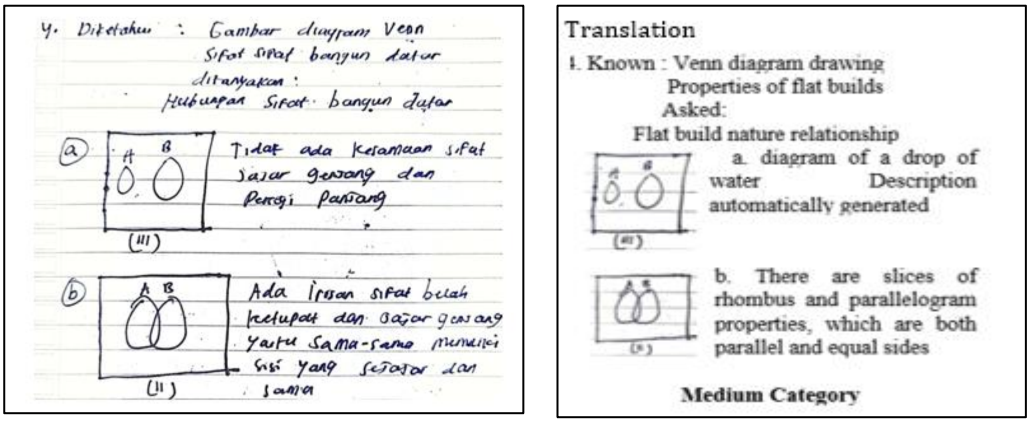


Figure 4. Medium category student answers on question with logic indicators

between properties of plane shapes, these students generally follow an orderly process in solving the problem and attempt to illustrate relationships using Venn diagrams. However, their responses reveal conceptual gaps, particularly in understanding the classification of geometric figures. For example, students often fail to recognize that a rectangle is a special case of a parallelogram, despite claiming to remember the properties of plane shapes. As one student stated, *"I forgot that a rectangle can be considered a special case of a parallelogram. However, I remember the properties of a plane shape."* This indicates their memory of properties is fragmented and poorly connected to broader geometric classifications.

A standard error found in this group is related to encoding the process of forming and articulating correct conclusions. One student mentioned, *"I feel confident in the answer I wrote in question number 4. I think this question is quite difficult because there are many properties in each plane shape."* Despite an incorrect conclusion, this confidence suggests surface-level familiarity rather than deep comprehension. Students may recall specific properties but struggle to analyze them logically or connect them meaningfully within geometric structures.

Although using GeoGebra in learning helps make abstract relationships more concrete, students in this category still face challenges in optimally applying the tool. Their difficulties likely stem from a tendency to memorize geometric facts without truly understanding the underlying relationships. Analytical thinking, especially in geometry, requires extended, meaningful practice that promotes lasting conceptual retention.

The findings suggest that integrating the GeoGebra application with consistent writing activities can support students in this category. Students are encouraged to describe known information, construct logical steps, and formulate their own conclusions through writing. This process not only strengthens understanding but also enhances memory and conceptual clarity. As highlighted by (Chasanah & Usodo, 2020; Kazemian et al., 2021), writing in mathematics, especially in geometry, is a critical tool for developing deeper conceptual understanding, analytical skills, and reflective thinking. Writing allows students to connect theory with practice, articulate their reasoning, and engage more actively with geometric ideas (Graham et al., 2020; Santos & Barbosa, 2023).

Analysis of low geometry skills category

Figure 5 presents the excerpt of a low category student's answer in question number 4. Students in the low geometry skill category demonstrate considerable challenges in applying logical and deductive reasoning, as demonstrated in their responses to question number 4, which assesses their ability to analyze and understand relationships between the properties of plane shapes. One major issue is their inability to transform the information provided into a broader context. Specifically, they struggle to group and relate properties using Venn diagrams. A clear example is a student's statement: *"I do not understand how to read Venn diagrams and what they have to do with the properties of parallelograms and rectangles."* This reflects a fundamental gap in understanding

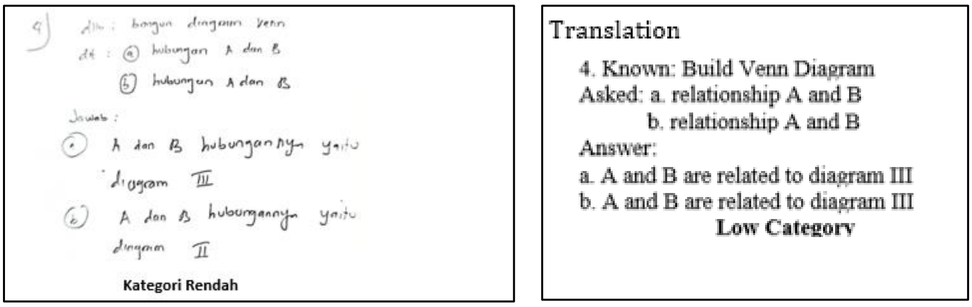


Figure 5. Low category student answers on question with logic indicators

the diagram's purpose and the conceptual relationships between different geometric figures.

Regarding process skills, students in this category often do not write down the steps needed to solve the problem. Their responses typically include what is known and what is being asked, indicating some willingness to engage with the task. However, they fail to use the necessary reasoning or analytical steps to bridge the gap between known information and a logical conclusion. One student admitted, *"I forgot the properties of plane shapes and did not understand how to see the relationship between the two shapes."* This suggests a lack of recall and a weak conceptual structure related to geometric classifications.

Encoding errors are also common, as students often provide incorrect or incomplete conclusions due to confusion or a lack of understanding. One student stated, *"I believe my answer is wrong because I do not understand."* This reveals a lack of confidence rooted in conceptual uncertainty, particularly in distinguishing and relating the properties of parallelograms, rectangles, and other plane shapes.

The students' inability to complete this task can be attributed to limited experience with abstract reasoning and inadequate exposure to representational tools such as Venn diagrams. Although these tools were introduced in previous lessons, students showed difficulty applying them independently. Therefore, to support students in this category, a more meaningful and structured learning approach is essential, one that helps build foundational understanding while developing abstract and logical thinking skills. Geometry inherently involves abstraction and generalization, and logical skills enable students to recognize patterns and apply general principles across different geometric contexts.

Integrating the GeoGebra application into learning provides a powerful solution to this challenge. Through dynamic visualization, GeoGebra allows students to explore relationships among geometric properties concretely and interactively. Using GeoGebra helps provide representational support, allowing students to understand better and generalize geometric relationships (Seloane et al., 2023). To maximize its impact, GeoGebra should be accompanied by scaffolded writing and reasoning tasks, enabling students to see relationships and articulate them clearly and accurately. This approach can gradually strengthen both their logical reasoning and conceptual understanding.

Student's answer analysis on the logical indicators

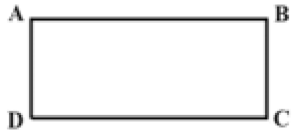
The second analysis is question number 3 as shown in Figure 6, a basic geometry skills question with draw indicators, along with the student's answer.

Analysis of high geometry skills category

Figure 7 displays the excerpt of a high category student's answer in question number 3, the geometric skills question with drawing indicators. In Figure 7, students in the high category demonstrated a strong understanding of geometric concepts and problem-solving strategies, as shown in their responses to question number 3, which involved calculating the area of a rectangle based on given information. The student approached the problem systematically, beginning with interpreting the question, constructing an accurate geometric drawing, and outlining the steps clearly. This reflects the student's achievement in the drawing indicator, which involves using geometric representations or constructions to communicate and solve problems. The drawing

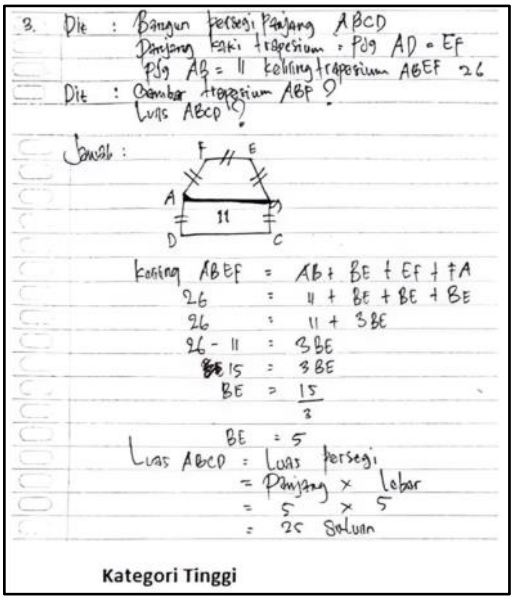
Question

Notice the rectangular build ABCD.



Draw an isosceles ABEF trapezoid whose longest base is the AB side. It is known that the length of the trapezoidal leg is equal to the length of the AD and EF sides. If it is known that the length of the AB side is 11 units and the circumference of the ABEF trapezoid is 26 units, then determine the area of the ABCD rectangle

Figure 6. Drawing indicator geometry skills questions



Translation

3. Given:

Rectangle ABCD

The length of the trapezoid leg = length of AD = EF

Length of AB = 11

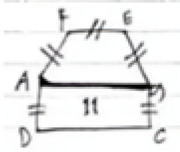
Perimeter of trapezoid ABEF = 26

Question:

Draw trapezoid ABF

Find the area of rectangle ABCD

Answer:



Perimeter of ABEF = AB + BE + EF + FA

26 = 11 + BE + BE + BE

26 – 11 = 3BE

15 = 3BE

BE = 15 ÷ 3

BE = 5

Area of ABCD = Area of a square

= length × width

= 5 × 5

= 25 units

High Category

Giver

Quest

Figure 7. High category student answers on question with drawing indicators

included all relevant dimensions and elements, helping to simplify the task and clarify the reasoning process. The student stated, "I'm confiden*t I wrote the correct answer. At first, question number 3 seemed difficult, but after I drew each part based on the given information, it turned out to be very easy."*

Despite the structured approach and confident execution, the student made a crucial error in the encoding phase, specifically in the final step of the calculation. The student mistakenly substituted the length of the rectangle as five units instead of the correct value, 11 units, which resulted in an incorrect computation of the rectangle's area. This type of error suggests a lapse in attention to detail rather than a lack of conceptual understanding.

Such mistakes highlight the importance of developing students' habits of double-checking and validating their final answers, even when the problem-solving process appears to be correct. While students in this category generally show advanced problem-solving and visualization skills, they still benefit from being encouraged to practice careful verification of calculations. With continued practice, including structured reflection and feedback, students at this level can further refine their precision and accuracy in mathematical problem-solving.

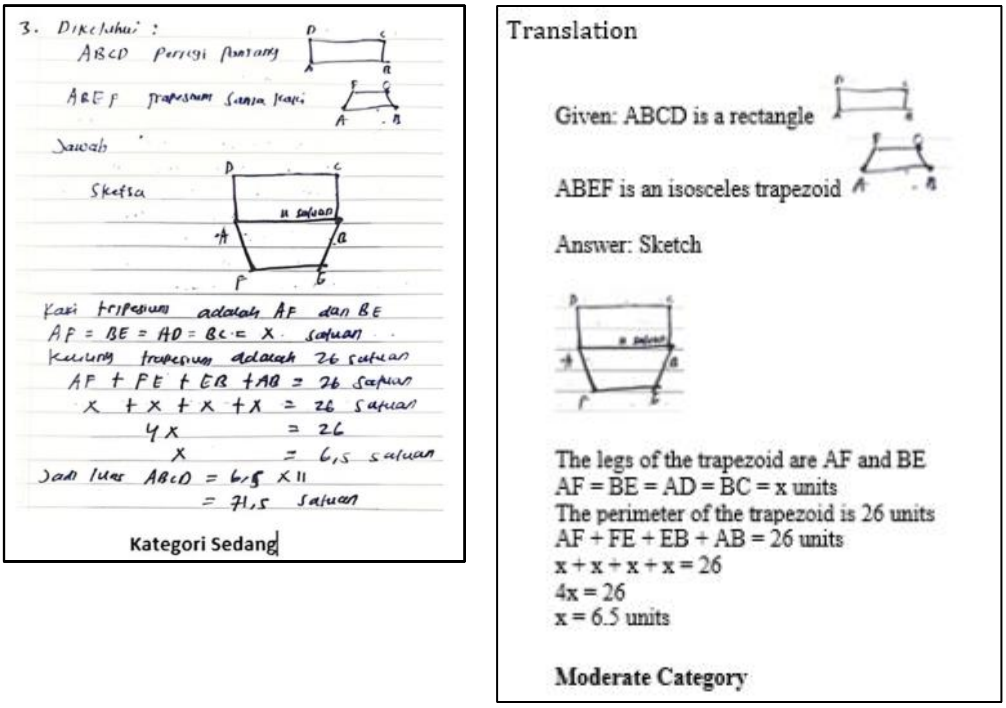


Figure 8. Medium category student answers on question with drawing indicators

Analysis of medium geometry skills category

Figure 8 shows the excerpt of a medium category student's answer in question with drawing indicators. Students in the medium category show a moderate level of understanding in solving geometry problems, but still make procedural and conceptual errors that affect the accuracy of their final answers, as shown in Figure 8. In question number 3, the student successfully applied the drawing indicator, which involves using geometric diagrams or constructions to interpret and solve problems. The student could represent the word problem with an appropriate drawing, indicating an ability to visualize the scenario geometrically. As noted in their statement, *"At first, I had difficulty drawing the trapezoid, but after trying, I felt confident that my drawing was correct. I enjoy solving problems that involve diagrams."* This reflects a positive attitude toward visual problem-solving and a developing skill in geometric representation.

However, an error occurred in the process skill aspect, specifically when the student incorrectly applied the formula for the perimeter of a trapezoid by substituting the wrong value for line AB. This mistake led to an incorrect final result. The miscalculation suggests that while the student could interpret the diagram, they lacked precision in applying the correct measurements. Additionally, the student made an encoding error by incorrectly calculating the area of rectangle ABCD. Although they expressed confidence in their answer, *"I'm confident that my answer was correct, but it turns out there was a mistake in calculating the length of the sides,"* the outcome revealed gaps in executing the final steps of the problem.

Overall, students in this category need more consistent practice with procedural accuracy and self-monitoring strategies. They benefit from being explicitly encouraged to review their work after solving problems and to carefully extract and record the given information before proceeding to calculations. Reinforcing these habits can help bridge the gap between correct conceptual understanding and accurate execution, enabling students to improve their confidence and mathematical precision.

Analysis of low geometry skills category

Figure 9 demonstrates the excerpt of a low category student's answer in question with drawing indicators. Students in the low category exhibited significant difficulties in understanding and solving geometry problems, particularly in question 3, which assessed the drawing indicator's ability to use geometric diagrams or constructions from various perspectives to communicate and solve problems.

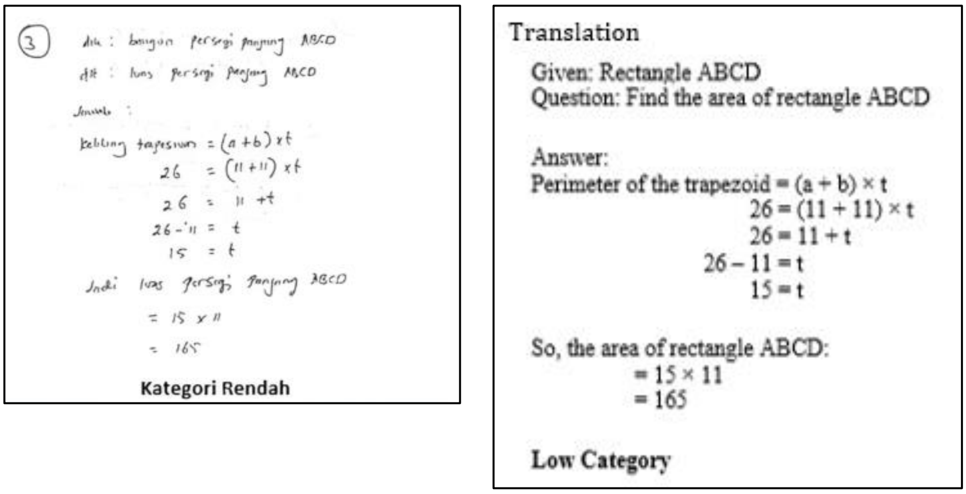


Figure 9. Low category student answers on question with drawing indicators

The student demonstrated an apparent lack of comprehension regarding the geometric context and terminology used in the question. As expressed in their statement, *"I wasn't sure what was meant by the trapezoid leg length being equal to the length of sides AD and EF. I think I need to review the definition,"* the student did not understand that the legs of a trapezoid refer to its non-parallel sides. This fundamental misunderstanding prevented them from grasping the core concept needed to solve the problem correctly.

The student failed in complete the transformation stage to represent the problem information in diagrammatic form. They could not create a visual sketch of the trapezoid based on the data provided in the problem. Their confusion is reflected in the statement, *"I was confused about how to draw trapezoid ABEF. I became unsure about drawing it after reading that one of the bases had to be side AB. That sentence confused me."* This indicates a struggle with interpreting spatial and relational information, which is critical in geometry.

The student also made errors in the process skill domain by misapplying the formula for the perimeter of the trapezoid and substituting incorrect side lengths. This procedural mistake suggests that, beyond conceptual misunderstanding, the student had not internalized the necessary formulas or how to apply them appropriately. They admitted, *"I'm not confident in my answer; the question was too difficult and I forgot the formula,"* signaling a need for more foundational practice and support.

Lastly, the encoding error was evident in the incorrect calculation of the area of rectangle ABCD. Despite knowing the formula, the student struggled to apply it due to a lack of clarity in interpreting the problem. As they explained, *"I know the formula for a rectangle, but I had trouble understanding the question,"* it became clear that conceptual confusion interfered with successful problem-solving.

Students in this category face challenges: difficulty comprehending geometric terms and relationships, inability to translate textual information into visual form, and procedural weaknesses in solving standard geometry problems. To support these students, instructional strategies should strengthen conceptual understanding by explicitly teaching geometric definitions and relationships. In addition, consistent practice in visualizing and drawing geometric figures, combined with scaffolded guidance in writing down relevant information, can help bridge the gap between understanding and application. Training students to organize information systematically, symbolically, and diagrammatically will enhance their ability to interpret problems and develop accurate solutions.

DISCUSSION

As shown in Figure 1, question 4 exemplifies the logic component within the students' geometry skill indicators. This statement refers to the ability of students to use logical thinking processes in understanding and solving geometry problems. In this case, students are expected to be able to apply the principles of mathematical logic to analyze the relationship between the properties of geometric plane shapes and draw valid conclusions from the information provided. This opinion is also supported by previous research, which states that the ability to solve mathematical problems is greatly influenced by logical spatial intelligence to help students analyze problem situations logically, then identify the right solution and get logical conclusions based on relevant arguments and facts (Aziz et al., 2020).

The results of students' answers to question 4, analyzed using Newman's procedure and grouped by ability levels (high, medium, and low), are summarized in Table 6. It was found that students in the high and medium categories made mistakes primarily in process skills and encoding. The student's mistake is in analyzing the properties of plane shapes. Students do not describe the properties of plane shapes and do not describe Venn diagrams based on the description of these properties to see the relationships between the sets, thus giving the wrong conclusions. However, it is known that students write systematic problem-solving and can compose arguments to prove statements; this is one of the key aspects of logic. Conversely, students with low geometry skills do not exhibit this behavior and make transformation mistakes because they do not convert the information into broader information, thus making more mistakes and coming to the wrong conclusion. Logical-mathematical intelligence involves the skill of processing facts using logic to analyze problems and formulate solutions in a logical order (Oljayevna & Shavkatovna, 2020). Using the Geogebra application is necessary to hone students' geometry skills, especially in logical indicators. However, it requires more specific activities to optimize it, namely writing activities. In other words, the Geogebra application is accompanied by specific mathematical writing activities that can optimize students' geometry skills, especially logical indicators.

From the analysis of the answers provided by students for question number 3, which measures the indicator of geometric thinking skills, namely drawing, it can be concluded that students' ability to represent geometric information in the form of drawings varies. Students in the high category demonstrate a good understanding of concepts and drawing skills, but still lack accuracy in the final calculation stage, especially in substituting values. Those in the medium proficiency group possess the ability to understand and draw geometric shapes, but still make mistakes in writing formulas and calculating values used. Meanwhile, students in the low category cannot yet represent the problem information in the form of drawings and show difficulties in understanding basic geometric concepts, such as the definition of trapezoid legs, as well as in performing calculations and drawing conclusions.

This indicates that not all students have fully mastered drawing skills as a tool for geometric thinking. According to Francis, (2022); Mainali (2021), visual representation through drawings plays a critical role in developing mathematical understanding by supporting conceptualization and communication. Furthermore, Van Hiele's theory emphasizes that geometric thinking progresses through levels that require students to interact with visual and abstract representations to build deeper understanding (Fachrudin & Juniati, 2023; Mahlaba & Mudaly, 2022). Therefore, learning should emphasize visualization practice, accuracy in problem-solving processes, and habituation in sequentially writing information in symbolic and graphical forms. The implementation of visual-oriented learning tools like Geogebra, which has been proven by Hamidah et al. (2024) to enhance students' ability to manipulate and understand geometric concepts dynamically, combined with mathematical writing activities, is also recommended to help students develop their logical and geometric representation skills more optimally.

Analyzing students' work on the drawing and logic indicators reveals a close relationship between visual representation skills and logical thinking abilities in understanding geometric concepts. The drawing indicator requires students to accurately represent geometric information through drawings or geometric constructions to communicate and explain concepts. Meanwhile, the logic indicator requires students to analyze and systematically connect information, such as describing the properties of plane shapes and using Venn diagrams to draw correct conclusions. Research by van Garderen et al. (2021) highlights that visual representations serve as a fundamental cognitive tool to facilitate the transition between different registers of mathematical reasoning, thereby enhancing logical thought processes. Furthermore, Medina Herrera et al., (2024) emphasize that visualization is deeply intertwined with mathematical logic, allowing learners to construct meaning and develop logical arguments based on visual input. Students with good drawing skills can better visualize problems, which supports logical thinking processes in analyzing and solving problems. However, without adequate logical skills, students tend to misinterpret information and draw incorrect conclusions, a problem also noted by Ghasemi et al. (2022) regarding difficulties in linking intuition (often based on visual impressions) with formal logical reasoning. Conversely, students with strong logical abilities can organize and process information systematically, which also aids in creating accurate geometric drawings, consistent with the findings of Van Hiele's levels of geometric thought, where logical reasoning complements visual understanding to achieve higher levels of geometric competence.

CONCLUSION

The research findings show that utilizing the GeoGebra application in geometry learning contributes positively to the development of students' geometry skills, particularly in enhancing logical reasoning and drawing abilities. Students who participated in GeoGebra-based geometry learning showed significant improvement in solving problems that required deductive reasoning, pattern recognition, and accurate visual representation of geometric objects. These improvements reflect technical growth and the advancement of geometry skills, including the integration of visual and logical abilities to understand and solve geometric problems meaningfully.

Logical reasoning and drawing abilities were found to be interrelated and form a critical foundation of students' geometry skills. Students with strong drawing skills but weak logical reasoning often struggled to arrive at accurate conclusions. Conversely, those with strong logical reasoning still require sufficient visual skills to represent abstract concepts concretely. Using GeoGebra supports the integration of these two skills by allowing students to manipulate geometric objects visually while encouraging analytical thinking and logical deduction based on the constructions they create.

Moreover, an instructional approach combining GeoGebra with mathematical writing activities has proven effective in simultaneously developing visual and logical components of students' geometry skills. Therefore, geometry learning should not treat drawing and reasoning as isolated abilities, but rather emphasize their interaction within the broader context of developing comprehensive geometry skills, including but not limited to geometric thinking.

As an implication, educators are encouraged to integrate visual tools such as GeoGebra into their instruction strategically. They also allow students to articulate their understanding through visual and logical representations. This holistic approach is expected to support the optimal and sustainable development of students' geometry skills.

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AUTHORS' DECLARATION

Authors' contributions	H: conceptualizing the study, conducting the literature review, designing the research instruments, analyzing the data, presenting the results and discussion, and drafting and proofreading the manuscript. JWK: contributing to the literature review, peer debriefing, and proofreading the manuscript. SC and ES: validating the research instruments, engaging in peer debriefing, contributing to the literature review, and proofreading the final document. All authors reviewed and approved the final version of the manuscript.
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Competing interests

The authors affirm that there are no conflicts of interest associated with the publication of this paper. This manuscript is entirely original and has not been previously published or submitted for publication in any other venue.

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