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The Presence of Writing Indicators in Geometry Skills: Evaluation of Errors Based on the Newman Procedure

Hamidah[1]*, Syamsul Hidayat[2], Dewi Surani[3], Jaka Wijaya Kusuma[1]

[1]Mathematics Education Department, Universitas Bina Bangsa, Indonesia, [2]Department of Management, Universitas Bina Bangsa, Indonesia, [3]Department of Information Technology Education, Universitas Bina Bangsa, Indonesia. *Corresponding Author's Email: shiroimida@gmail.com

Abstract

This study aims to examine students' geometry skills after being given learning with the GeoGebra application and evaluate the results of students' work based on Newman's procedure after solving geometry skill problems. This study uses quantitative research methods in the first stage to obtain quantitative data. In the second stage, qualitative methods are used to deepen, expand, and prove quantitative data. The research subjects were selected by purposive sampling, namely second-semester students of mathematics education at Bina Bangsa University in two classes. The instruments used were geometry skills tests and interview sheets. The quantitative data analysis technique uses a percentage formula and an average difference test. Furthermore, quantitative data analysis techniques use data analysis consisting of data reduction, data presentation, and drawing conclusions or verification. The results showed that learning Geometry with the GeoGebra application had a positive influence on improving students' geometry skills. Furthermore, in addition to the five indicators of geometry skills it was found that writing became an important indicator as part of the benchmark of students' geometry skills. The writing indicator in question is being able to clearly write information and ideas in various perspectives and explain the geometric problem-solving process plan.

Keywords: Errors Based, GeoGebra, Geometry Skills, Newman Procedure, Writing Indicators.

Introduction

Basic geometry skills are important for academic development in the context of mathematics education as well as in everyday life, as they form a solid foundation for geometric thinking, critical thinking, problem-solving, and understanding the problems of the world around us. The development of basic geometry skills strengthens students' geometric thinking ability (1). In particular, it also mentions that basic skills in visual geometry are one of the must-haves for an accurate understanding of geometry. Meanwhile, it is stated that when a person has to reach the level of informal deductive thinking based on Van Hiele's level of thinking, it means that the person must first master the basic skills of geometry (2). Having good basic geometry skills is the foundation for geometry thinking skills. Basic geometry skills are the practical and technical foundations in geometry, while geometry thinking abilities include more complex cognitive aspects of understanding and processing geometric information. Basic skills provide the foundation necessary to develop higher geometric thinking abilities. Basic geometry skills refer to the understanding and mastery of fundamental concepts in geometry as well as the ability to apply them in a variety of situations (3). Geometry skills according to Jebur, refers to a set of mathematical abilities and knowledge related to the study of drawing and designing geometric shapes, using logical and deductive thinking in solving geometric problems, and applying geometric concepts in a variety of contexts, including real-life situations (4). The indicators of geometry skills consist of five skills, namely visual, verbal, drawing, logic, and applied (4–8). Meanwhile, the ability to think geometry is the ability to understand, analyze, and manipulate geometric information to solve problems related to objects, shapes, spaces, and geometric relationships (9). Van Hiele also divides geometric thinking skills into five levels, namely level 0 (visualization), level 1 (analysis), level 2 (abstraction), level 3 (deduction), and level 4 (rigor). Based on the results of several previous studies, it is known that students' geometric

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thinking skills are still very low. The following are the results of previous research on students' geometry skills. Results of the first study, it is known that only 49% of high school students are able to reach level 1 (analysis) of Van Hiele's geometric thinking level, and 54% of students are able to achieve level 3 (abstraction) of Van Hiele's geometric thinking level (10). Results of further research, it is known that only 9.7% of students managed to reach level 3 (abstraction) of Van Hiele's geometric thinking level, 65% of students were at level 1 (analysis), and the rest were at level 0 (visualization) (11). Selanjutnya, it is known that 42.5% of students cannot reach the level of Van Hiele's geometric thinking at all, 33% of students reach level 1 (visualization), 22.5% reach level 2 (analysis), 1.5% reach level 3 (order) and only 0.5% reach level 4 (deduction) (12). The results of Altun's research are also not much different, namely the level of Van Hiele's geometric thinking of students is known to be mostly stacked at level 1 (66%), namely (visualization), 26% to level 2, namely (analysis) and 8% to level 3, namely (order) (13). From the results of the research of (10–13) concluded that the Van Hiele geometry thinking level of students is mostly only up to level 0 (visualization) and only a small part is able to reach the highest level 1 (analysis) and level 2 (abstraction). Furthermore, based on the results of previous research on the level of students' geometric thinking ability, it is known that they are still at a level that is not much different from the level of students' ability. Other research results, it is known that research on students' geometric thinking ability are known that students only reach level 2 Van Hiele (14). Furthermore, the results of the research by Putri's show that the highest level of Van Hiele geometry thinking achieved by students is level 1 (analysis), of which 15% of students reach the pre-0 level and 50% of students at level 0 (visualization), and 35% of students at level 1 (analysis) (15). It is also known that on students' geometric thinking ability showed that 50% of students only reached stage 1 or the introduction stage reviewed from Van Hiele's thinking stage (16). The results of the subsequent study were found to be 30.65% of students at the pre-visualization level, 21.51% of students at level 0 (visualization), 29.03% of students at level 1 (analysis), 16.67% of students at level 2 (informal deduction), and only 2.15% of students at level 3 (deduction), and 0.00% of students at the rigor level (17). Study showed that of the 105 students studied, 20 (19.05%) students were at the pre-0 level, 14 (13.33%) students were at level 0 (visualization), 38 (36.19%) students were at level 1 (analysis), 20 (19.05) students were at level 2 (abstraction), 12 (11.43%) students were at level 3 (deduction), and 1 (0.95%) student was at level 4 (rigor) (18). Based on the results of the research concluded that the level of Van Hiele geometry thinking of students is mostly up to level 2 (abstraction), there are a small number who are able to reach level 3 (deduction), and there is only 1 student who is able to reach level 4 (rigor) (14–18). In conventional teaching, geometry is taught textually, i.e. the concept of geometry is not related to the actual word or the real life of the learner (19). Furthermore, it is known that students know the details and concepts to be used but are less able to relate the basic concepts of geometry to the concepts they have just learned (20). The results of previous research were known that students' difficulty understanding geometry occurs because they have difficulty thinking about abstract shapes, analyzing the properties of observed geometric objects, and presenting geometric objects in the form of images (21). This explains that one of the difficulties that students experience in learning geometry is due to conventional learning. Sometimes, learning geometry conventionally may be less effective for some students. Learning geometry conventionally tends to involve theoretical and abstract learning, which is difficult to relate to the real world. Geometry learning must be interactive and according to the needs of students so that it is interesting during the learning process (21). This is supported by the Anwar's opinion, that learning with the help of technology is one of the interactive learning that is able to create geometric objects and can be presented dynamically and accurately, so that learning becomes interesting and has a great influence on students' geometric thinking skills (21). GeoGebra is dynamic and interactive mathematical software, which is not only used to visualize mathematical concepts, but also to integrate mathematics learning with a more active and experience-based approach (22–24). Mathematics learning with the GeoGebra application provides many significant benefits for students and the overall mathematics learning process (25–28). GeoGebra allows

students to visually illustrate mathematical concepts (29). Students can create graphs and draw geometric shapes interactively so that it helps students to understand abstract concepts in a more concrete and visual way. With GeoGebra, students can change parameters and see how those changes affect the graphical representation of the mathematical concepts studied. For example, changing the shape of a geometric shape or manipulating it to see the changes happening directly. This research will apply geometry learning with the GeoGebra application to analyze students' geometry skills and mistakes that students tend to make in solving geometry problems. It is hoped that the results of this research can provide significant benefits in improving the geometry learning process and helping students overcome the challenges they face. The Newman error analysis method was first introduced in 1977 by Anne Newman, a mathematics teacher in Australia. The Newman procedure is often used to determine different types of student errors in doing math problems in many countries such as India, Malaysia, Thailand, Australia, and others (30). Furthermore, it is known that the Newman procedure is a method used to analyze student errors, causes of errors, and analyze student errors in answering sentence-based problems (31). So, for the analysis of student errors in solving geometry skills problems in this study, the Newman procedure will be used. The objectives of this study are: 1) to compare the improvement of students' geometry skills who are given learning with the GeoGebra application with those who do not use the GeoGebra application; 2) analyze students' geometry skills after being given Geometry learning with the GeoGebra application.

Methodology

This study uses quantitative and qualitative research methods, in the first stage it uses quantitative methods to obtain quantitative data, then in the second stage it uses qualitative methods to deepen, expand, and prove quantitative data. Quantitative research is a research method that relies on the collection and analysis of numerical data to measure, describe, explain, or predict, as well as make generalizations broadly (32). The Newman procedure is one of the numerical data used to measure, describe, explain, or predict, as well as make generalizations to a student's geometry skills. While qualitative research is interactive research in which researchers are involved in continuous and continuous experiences with participants, this involvement will later give rise to a series of strategic, ethical, and personal issues in the qualitative research process (33). The subject of the research is students who will be given Geometry lessons. The selection of subjects by purposive sampling, namely mathematics education students at Bina Bangsa University, consists of two classes. The second semester was chosen from all the semesters, namely those who will take the Geometry course. The instruments used are tests to assess students' geometry skills after learning and interview sheets to get feedback from students about learning geometry with the GeoGebra application and about the difficulties that students face in solving geometry skill problems. The test instrument is in the form of five description questions made based on five indicators of students' geometry skills that have been tested and have been declared valid for use. Data collection is to provide geometry skills pretests to students before learning and geometry skills postes to students after learning Geometry with the GeoGebra application. The learning carried out in the Geometry course in the field of triangle and quadrilateral material for 4 meetings. After giving postes, at the next meeting, interviews were conducted with three students who were selected based on the high, medium, and low categories. The quantitative data analysis technique uses a percentage formula and an average difference test; previously a normality test and a homogeneity test were carried out. Furthermore, quantitative data analysis techniques use data analysis consisting of data reduction, data presentation, and conclusion drawing or verification (34). This technique is called triangulation because it combines data collection techniques, geometry skills tests, and interviews. According to (36) triangulation is a method that uses several data sources to achieve data convergence so that valid data is achieved. Triangulation techniques are carried out by the researcher to check information/data between the results of the interview and the documents or the results of the student's work to complete the given questions. By conducting triangulation, the researcher collected data as well as evaluated the data of students' geometry skills.

Results and Discussion

Results of Definition of Students' Geometry Skills Before and After Learning

The data from the geometry skills test of students before and after learning are presented in the following table.

Table 1: Descriptive Statistical Results of the Geometry Skills Test

	Experiment			Control		
	Pretest	**Post test**	**Gain**	**Pretest**	**Post test**	**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 1 shows that the average scores of the geometry skills of the experimental class is better than that of the control class. The increase in geometry skills of both classes also showed that the experimental class improved better than the control class. Based on the N-gain categorization, it is known that the experimental class is in the effective category with an N-gain value of 0.78, which is a percentage of 78%. Meanwhile, the control class is in the N-gain category with a value of 0.57, which is a percentage of 57%. This means that in general, the experimental class experienced a higher increase than the control class.

Results of Normality and Homogeneity

Based on the normality test, it was found that the significant value of the N-gain data of the experimental class and the control class was 0.65 and 0.25, respectively, which was more than 0.05. This means that the data of the experimental class and the control class are declared to be normally distributed. Furthermore, based on the homogeneity test, the results of the SPSS test were obtained with a significant value of 0.88, which is more than 0.05, meaning that the data of the two classes are homogeneous data.

Average Difference Test Results

Because the data is normally distributed and homogeneous, the average difference hypothesis test uses the T test. The following results of the calculation of the T test with SPSS are presented in the following table.

Table 2: Test Results Paired t test

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

Based on the table of t-test results above, Table 2 knows that the Sig. value is 0.000, which is less than 0.05. This means that the hypothesis (Ha) is accepted, namely there is a significant difference in the improvement of geometry skills between students between the experimental class and the control class. Judging from the average N-gain of geometry skills of the two classes, it is known that the experimental class is higher than the control class. This information explains that the use of geometry learning with the GeoGebra application has a better influence on improving students' geometry skills than learning geometry without using the GeoGebra application.

Evaluating Students' Geometry Skills

Overall, it has been known that learning Geometry with the GeoGebra application is effective on students' geometry skills. The next analysis is on students' geometry skills. The data analyzed were student geometry skill test data and interview results.

Data Reduction

The grouping of students' geometry skills was taken from postes data with high, medium, and low

categories. Furthermore, one student representing each category was selected. The depiction of the distribution of the postes scores of the experimental class group is classified in the form of intervals. Based on the scores of the geometry skills of the experimental class students, the distribution of scores is categorized into three groups, namely high, medium, and low (37). The following are the results of data processing to classify student scores.

High Category : 80 ≤ skor ≤ 100
Medium Category : 60 ≤ skor < 80
Low Category : 0 ≤ skor < 60

Based on this classification, the postes score data of the two groups is presented in the following table.

Table 3: Number of Students by Student Geometry Skills Category

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

Table 3 Shows that more than 50% of students are in the high category of geometry skills. However, there are nine students who need analysis in order to improve their geometry skills. Analysis will be carried out to all categories to obtain broader information. Each category will be selected by one student to analyze the results of their work and be interviewed. The total number of students whose work was analyzed in solving geometry problems based on the Geometry skill category was three students, namely one student each from each indicator. These three students will be interviewed and analyzed for their work. There are five categories of errors based on Newman's procedures, namely (1) reading, (2) comprehension, (3) transformation, (4) process skill, and (5) encoding (38–40). This category is a guideline in seeing the mistakes of students solving geometry skills problems.

Data Presentation

The following is a description of student errors based on the Newman procedure carried out by students of the experimental class which totaled 23 students.

Table 4: Number of Students Who Made Mistakes Based on the Newman Procedure

	Number of Students Who Make Mistakes (n=23)					Total	Percentage
	No 1 Visual	No 2 Verbal	No 3 Drawing	No 4 Logic	No 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
Total	25	26	50	55	9		

Table 4 shows that the most mistakes made by students are in question number 4 with a total of 55 errors. Judging from the error category, namely out of 23 students, there were 23 students who made mistakes in the encoding category. If analyzed further, it is known that there are also many errors in process skills, namely 17 out of 23 students. Process skills are errors in process skills, namely errors in applying steps in solving problems. This clearly shows that, if students make mistakes in process skills, it is likely that students will also be wrong in representing the answer as a whole. This is true for other errors. For example, transformation errors are errors in transforming or transforming mathematical information into other forms. If you start from this mistake, then students are most likely to make mistakes in process skills and encoding. An interesting fact is known that the number of students who make mistakes based on the Newman procedure category is sequential, starting from the least is the reading error category, followed by the comprehension, transformation, process skill, and finally the most errors are the encoding category.

This shows that when students start making mistakes in the reading category, it means that it is likely that the student will make mistakes in other categories. The reason is that when students cannot read the important information from the questions and even do not understand what is asked from the questions, it is difficult for students to be correct in taking the next step and concluding the final answer correctly. Student errors based on Newman's procedures, starting from the categories of reading, comprehension, transformation, process skill, and encoding, each generally showed errors in writing. Whether it's writing down what is known from the problem, writing down what is asked, writing down changes in information into other forms of mathematics, writing down the stages of the completion process, to writing down the final result. So it is known that writing skills in geometry problems are very necessary. The following is a description of student errors based on the Newman procedure carried out by students of the experimental class who were randomly selected from the geometry skill category.

Table 5: Student Errors Based on Newman Procedure

Categories Geometry Skills	Student Errors Based on 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 Question	Improper encoding: (5) encoding	Improper Accuracy: (4) Process Skill, and (5) Encoding	true
Medium	true	Improper Accuracy: (4) Process Skill, and (5) Encoding	Improper Accuracy: (4) Process Skill, and (5) Encoding	Improper Accuracy: (4) Process Skill, and (5) Encoding	true
Low	Improper inaccuracy: (2) comprehension, (3) transformation, (4) process skill, and (5) encoding	Inaccurate: (3) transformation, (4) process skill, and (5) encoding	Improper inaccuracy: (2) comprehension, (3) transformation, (4) process skill, and (5) encoding	Inaccurate: (3) transformation, (4) process skill, and (5) encoding	Improper Accuracy: (4) Process Skill, and (5) Encoding

Table 5 shows that a general overview of the mistakes made by students in the high, medium and low categories. It is known that students with a low geometric teamwork category make many mistakes in almost all question numbers. In general, it can also be concluded that questions number 3 and 4 are classified as difficult questions according to students and question number 5 is classified as easy questions according to students. Furthermore, the results of the student's work for each question number will be analyzed from the geometry skill category, namely high, medium, and low. The question number 1 and the students' answers are as follows.

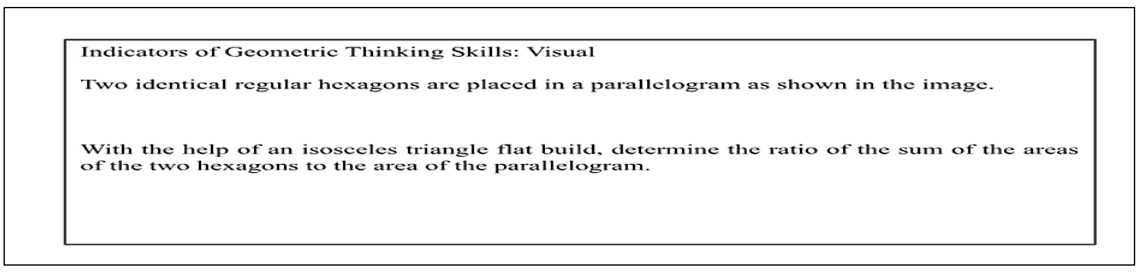


Figure 1: The Question Number 1

Figure 1 is an illustration of question number 1. Question number 1 represents one of the indicators of students' geometry skills, namely visual indicators. This statement refers to the ability of students to understand and apply the concept of geometry through their visual perception. Visual indicators in geometry skills are related to students' ability to recognize, describe,

and manipulate geometric objects visually. Question number 1 is designed to measure the extent to which students can see and understand the relationship between shape, size, position, and orientation of geometric objects by relying solely on visual observation. Thus, this question serves to evaluate the level of students' skills in understanding geometric concepts through the observation of images or diagrams without involving much complicated mathematical calculation.

The students' answers are:

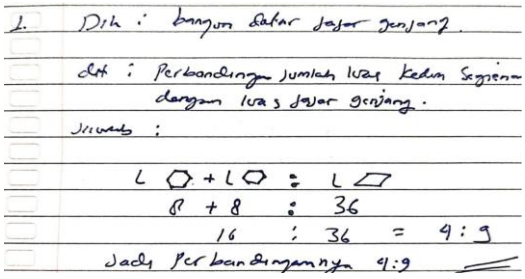
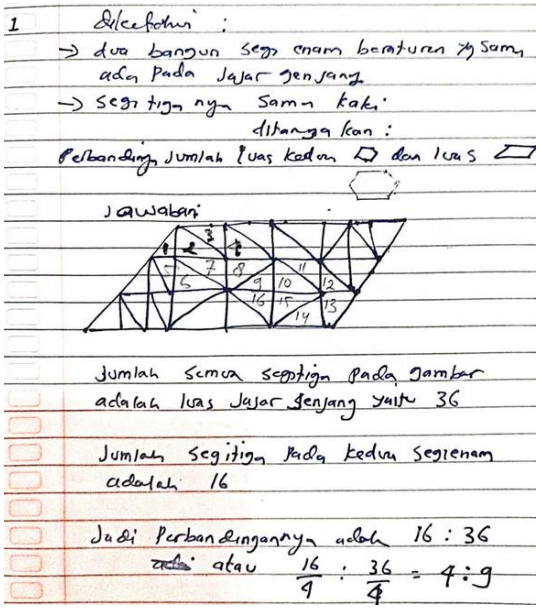
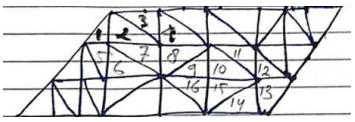
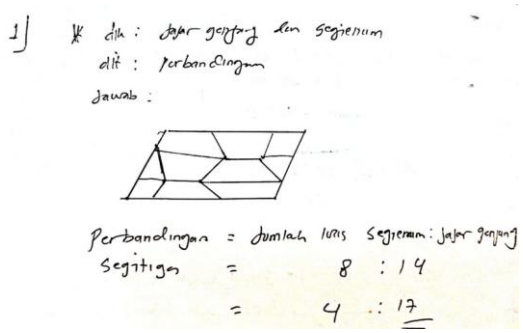
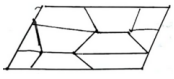
Student Answer	Translation
Kategori Tinggi  1. Dik : banyak datar jajar genjang. dit : Perbandingan jumlah luas kedua segienam dengan luas jajar genjang. Jawab : L ⬡ + L ⬡ : L ▱ 8 + 8 : 36 16 : 36 = 4 : 9 Jadi perbandingannya 4:9	High Category 1. Known: flat build parallelogram Asked: the comparison of the sum of the areas of the two hexagons with the area of the parallelogram. Answer: L ⬡ + L ⬡ : L ▱ 8 + 8 : 36 16 : 36 = 4 : 9 So the comparison 4 : 9
Kategori Sedang  1 Diketahui : → dua bangun segi enam beraturan yg sama ada pada jajar genjang → segitiga nya sama kaki. ditanyakan : Perbandingan jumlah luas kedua ⬡ dan luas ▱ Jawaban : Jumlah semua segitiga pada gambar adalah luas jajar genjang yaitu 36 Jumlah segitiga pada kedua segienam adalah 16 Jadi Perbandingannya adalah 16 : 36 atau $\frac{16}{4} : \frac{36}{4} = 4:9$	Medium Category 1. Known: -> two regular hexagons that are on a parallelogram -> the triangle is isosceles Asked: Comparison of the sum of the second area ⬡ and the area ▱ Answer:  The sum of all the triangles in the image is the area of the parallelogram which is 36 The number of triangles on both hexagons is 16 So the ratio is 16 : 36 Or 16/4 : 36/4 = 4 : 9
Kategori Rendah  1) dik : jajar genjang dan segienam dit : perbandingan jawab : Perbandingan = jumlah luas segienam : jajar genjang Segitiga = 8 : 14 = 4 : 17	Low Category 1. Known: parallelogram and hexagonal alignment Asked: comparison Answer:  Comparison = the sum of the area of the hexagon : parallelogram Triangle = 8 : 14 = 4 : 17

Figure 2: Student Answer Results Question Number 1

Figure 2 is the student's answer to question number 1 which is randomly selected from each category of students' geometry skills to analyze their errors. Based on Table 5, it is known that student errors based on Newman's procedure in question number 1, students with high and

medium categories do not make mistakes, but students with low categories make mistakes in comprehension, transformation, process skill, and encoding. In more detail, table 6 will be presented, namely a description of the analysis of students' answers to question number 1 according to Newman's procedure accompanied by the results of interviews with the students concerned.

Table 6: Description of Analysis of Student Answers to Question Number 1 Based on Newman Procedure

Category	Error Description and Interview Results	Analysis
High	Students have written the correct answer to question number 1. Students already understand the information provided in the question, especially in recognizing isosceles and hexagons and how to position these shapes in a parallelogram. Student statement: "When I look at the problem, I already understand that the number of triangles will be used to determine the area of a flat building. So the first step I did was to calculate the number of triangles in each flat shape that was asked. I was very interested in this kind of puzzle problem, because it felt like I was playing a game."	Students in the high category of geometry skills, gave the correct answer. The steps of the work are written very neatly, concisely, and clearly. The expected indicator in this question is visual skills, namely the ability of students to interpret and use information presented visually in the form of pictures to solve geometry problems. Students showed that they had met these indicators. In general, it is known that students' skills in conveying mathematical ideas and symbols in **written** form provide structured and correct answer results. Students already understand the information provided in the question, especially in recognizing isosceles and hexagons and how to position these shapes in a parallelogram. Students also fully understand the concept of the number of triangles and the flat area of money given to the problem, then **write it** in the steps to solve the problem. Students are also able to apply the information and steps prepared to calculate the ratio of flat building area. So, the representation of the answers given is correct.
Medium	Students have written the correct answer to question number 1. Student statement: "I initially thought that the problem given lacked data, because there was no unit of length in a flat building, so it was impossible to calculate the area. But after I redrew it, I found out that the triangle has the same size so that it can be used as a unit of area. I am happy with questions that invite deep thinking."	Students in the medium category of geometry skills gave the correct answer. Students showed that they had met the visual indicators. The steps of the work **are neatly written** and accompanied by pictures that help to understand the problem at hand. Students showed that they had the skills to **rewrite** the information in the questions well and include additional information in the form of picture captions so that they were better able to articulate their understanding of the mathematical concepts needed to solve

		geometry problems. Students can **write** in detail about how they apply the concept of the number of triangles as the area of other flat shapes, this step is the key to avoiding misunderstandings and finding solutions to problems.
Low	**Comprehension*:*** Mistake: Students do not fully understand the concepts of hexagonal square area and parallelogram area, as well as how to calculate them. Students try to describe the problem, but it does not help in understanding the problem and even becomes a cause of confusion. Students do not understand the keywords given in the questions, so they cannot solve the given questions. Student Statement: "I am confused about how to identify the position and relationship between a hexagon and a parallelogram, and I have difficulty understanding the concept of the area of a hexagon and how to calculate it. What exactly should I compare?" **Transformation*:*** Error: Students are wrong in transforming the information provided in the question into correct calculation steps. The triangle that has been provided is not used to determine the area of a flat building. Student Statement: "I'm not sure how to use an isosceles triangle to find the ratio of the area of a hexagon to the area of a parallelogram." **Process Skill*:*** Error: Students have difficulty applying the right formula or algorithm to calculate the area of a hexagon and the area of a parallelogram. Student Statement: "I don't know how to write down the formula or the steps I should use to calculate the area of the two buildings." **Encoding*:*** Error: Students make mistakes in expressing their answers mathematically; this is because the steps used in *the process skill* are also incorrect in the representation of the results. Student Statement: "I'm not sure how to write the answer in the correct mathematical form for the comparison of the area of the second build with the area of the parallelogram."	Students in the low category of geometry skills gave quite significant mistakes in working on problem number 1. Question number 1 is a visual indicator question. The difficulty of students in solving this problem lies in the lack of in-depth understanding of the concept of geometric building area presented in the figure, lack of understanding of how to use isosceles triangles to solve problems, and difficulties in applying information appropriately. Lack of skills for students in **rewriting** problems on questions so that they are wrong in choosing the steps to solve and solve them. Students' errors in **writing** information from problems affect accuracy so that it results in difficulties in arranging the correct solution steps, which in turn can lead to errors in solving geometry problems. Good writing skills involve the ability to organize ideas systematically and logically, so that students are able to structure calculation steps or mathematical arguments in a structured manner.

Table 6 is description of analysis of student answers to question number 1 based on newsman procedure. The work of students shows that students with high and medium categories of basic geometry skills tend to write down plans when solving problems either in the form of sentences, symbols, or formulas and write neat and concise answers. On the other hand, students with low geometry skills do not do it, so they tend to make many mistakes. The question number 2 and the students' answers are as follows. Indicators of Geometric Thinking Skills: Verbal it is known to

wake up rhombic. Which are the following characteristics of the rhombus, explain.

- Have a pair of right angles close to each other.
- The facing corners are equally large.
- The two diagonals intersect perpendicularly.
- Exactly have a pair of parallel sides.
- Parallel facing sides of equal length.

The students' answers are:

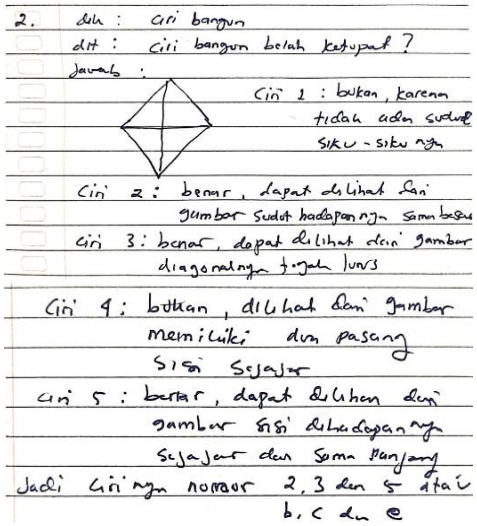
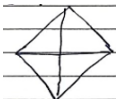
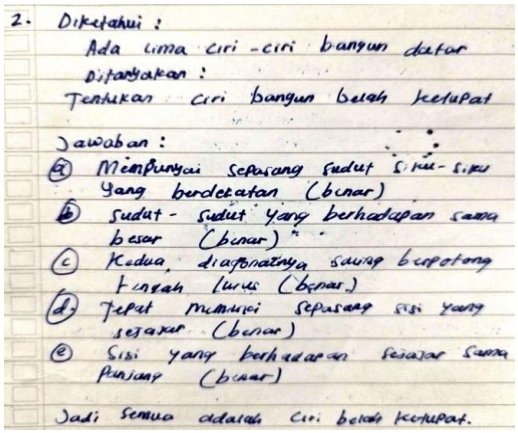
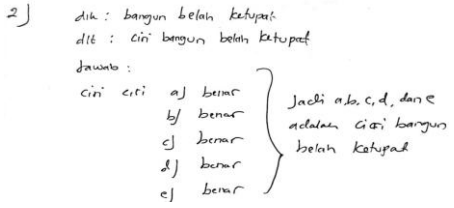
Kategori Tinggi  	High Category 2. Known: Wake Up Feature Asked: the characteristics of waking up a rhombus? Answer:  Feature 1: no, because there are no right angles Feature 2: true, as can be seen from the front corner picture is equally large Feature 3: correct, it can be seen from the diagonal image perpendicular Feature 4: no, judging from the picture it has two pairs of parallel sides Feature 5: true, it can be seen from the side picture in front of it parallel and the same length So the characteristics are numbers 2, 3, and 5 or b, c, and e
Kategori Sedang  	Medium Category 2. Known: the side of the data Asked: determine the characteristics of a rhombus Answer: a. have a pair of right angles close to each other (true) b. facing angles that are equally large (true) c. the two diagonals intersect perpendicular to each other (true) d. exactly have a pair of parallel sides (true) e. the side facing parallel is the same length (true) So all are the characteristics of the rhombus
Kategori Rendah  	Low Category 2. Known: rhombus Asked: characteristics of a rhombus Answer: Characteristics a) true b) true, c) true d) true, e) true So A, B, C, D and E are the characteristics of the rhombus

Figure 3: Results of Student Answers Question number 2

Figure 3 is the results of student answers question number two. Based on Table 5, it is known that student errors based on Newman's procedure in question number 2, students with high categories do not make mistakes, but students with medium categories make mistakes in process skills and encoding, and students with low categories make mistakes in transformation, process skills, and encoding. In more detail, table 7 will be presented, namely the description of the analysis of the student's answer to question number 2 according to the Newman procedure accompanied by the results of interviews with the students concerned.

Table 7: Description of Analysis of Student Answers on Question Number 2 Based on Newman Procedure

Category	Error Description and Interview Results	Analysis
High	High category students have given the correct answer. Student statement: "What I thought after seeing the question was to describe the shape of the rhombus, so that it would be easier for me to check the truth of each of the characteristics given."	High category students have answered question number 2 correctly. This means that it has met the verbal indicator, namely being able to convey an understanding of geometric concepts which are then written clearly using the right terms and notation. The results of the analysis of student answers are known that students are very careful and use their skills in **rewriting** question information in the form of pictures. This is done by students as a step to make it easier to understand the characteristics of the flat building provided. From the results of the answers, students clearly have a good understanding of the question material.
Medium	process skill Error: Students incorrectly stated that the first feature (a) and the fourth characteristic (d) are the "correct" characteristics of a rhombus. This means that students misunderstand the concept of adjacent right angles. Students thought that the rhombus had right angles in adjacent corners. Students also misunderstand the number of parallel side pairs on the rhombus. Student statement: "I think the rhombus has right angles in the adjacent corners, but it's not, ma'am. I also misunderstood the word "proper" in the question. " Encoding Error: Student mistakes at this stage are the impact of mistakes in the previous process. Students represent the results of their answers based on previous findings. Student statement: "I am not sure of the answer I gave. I can't help but see question number 2".	Students in the medium category are not right to give an answer to question number 2. This means that it has not met the verbal indicators. If analyzed from the results of the answers, students seem to be less thorough and in a hurry. Students do not carefully **write** down what is asked in the questions that ask students to provide explanations for the answers. If students try to **write** an explanation on each answer, then they are likely to know that the flat building features they write are true or false. The lack of one step written on the student's work is not **writing** an explanation of each flat building feature, so as to provide the wrong understanding and answer to the question. In general, it can be concluded that some geometric concepts in the shape of a rhombus require a deeper understanding. It is important for students to understand and **rewrite** well the definition and special properties of the rhombus such as facing angles, diagonals, parallel sides, and opposite sides in order to understand the questions in the question and then be able to answer the questions precisely and accurately in the context of geometry.
Low	Transformation Error: Students do not have a deep understanding of the geometric properties of rhombuses.	Low-category students have not been able to provide answers that meet expectations in question number 2. This means that students are not yet able to convey an understanding of the concept of geometry which is then written clearly using the right terms and

	Student statement: "I seem to have forgotten the shape of the rhombus and forgotten its characteristics." Process skill Error: The students' answers were neat by writing down what was known and what was asked. However, it does not carry out a structural process in solving problems. Student statement: "I don't understand about rhombuses, and I need more explanation about the definition of 'parallel' in geometry." Encoding Error: Because *the* process skill carried out gives the wrong result, the encoding is also wrong, which is the wrong representation of the final answer. Student statement: "I believe the answer I wrote is not correct".	notation. This is very clear from the results of the students' answers that have very little explanation, students do not understand correctly about the shape of the rhombus and what its characteristics are, especially students do not know that the rhombus does not have right angles in adjacent corners. Students also misassociate the concept of right angles with angles between parallel sides. Students believe that the answers they write are wrong answers. Students seem less accustomed to **rewriting** information from problems and writing down the steps to solve them either in symbols or pictures which of course is very useful for understanding and finding solutions to the problems faced.

Table 7 is a description of the analysis of students' answers to question number two based on Newman's procedure. Student work shows that students with a high category of basic geometry skills tend to write down plans when solving problems, whether in the form of sentences, symbols, or formulas, and write neat and concise answers. It is different with students whose geometry skills are medium and low who do not write down the plan well and collapse when solving Geometry problems, so they tend to make a lot of mistakes.

Drawing Conclusions

Based on the analysis carried out, the following conclusions were drawn about the geometry skills of students.

Table 8: Geometry Skills Indicators Before and After Learning with the GeoGebra Application

Number	Indicators of Geometry Skills After Learning	Indicators of Geometry Skills After Learning
1.	Visual	Visual
2.	Verbal	Verbal
3.	Drawing	Drawing
4.	Drawing	Drawing
5.	Applied	Applied
6.		Write

Table 8 explains that before being given learning with the GeoGebra application, it is known that geometry skills consist of five indicators, namely visual, verbal, drawing, logic, and applied. Furthermore, after being given learning with the GeoGebra application regularly and based on the results of the analysis of errors made by students in solving geometry skill problems, it was found that writing became an important indicator as part of the benchmark of students' geometry skills. The writing indicator in question is being able to clearly write information and ideas in various perspectives and explain the process of the geometry problem solving plan. Write information

and ideas in various perspectives and explain the geometric problem-solving process plan.

The Importance of Writing Indicators in Geometry Skills

The results of the analysis show that students often have difficulty in expressing clearly the geometric concepts they understand in writing. Students often face difficulties in communicating their understanding of geometry in writing. It includes an explanation of the steps to solve a geometry problem, formulate a concept, and convey mathematical arguments clearly. Students may face challenges in organizing and communicating their ideas related to geometric properties, such as writing explanations of how they calculate area or drawing sketches of flat buildings. The ability to write clearly and structured will help them communicate their understanding of geometry more effectively to others. Good writing skills are required to explain the steps in solving geometry problems, present arguments, and formulate concepts systematically.

Writing Indicators as Part of Geometry Skills

In the context of geometry skills, writing indicators include not only the ability to structure and write answers in a clear and structured format, but also the ability to clearly write down information and ideas in a variety of perspectives and explain the geometric problem-solving process plan. The writing indicator in question is being able to clearly write information and ideas in various perspectives and explain the process of the geometry problem solving plan. Writing allows students to sharpen their understanding of geometric concepts by summarizing, grouping, and organizing information in a meaningful way.

Theories that support writing learning include:

- The integration between language and mathematics is important to help students develop a deeper understanding of mathematical concepts (41, 42).
- Writing in mathematics not only helps students communicate their thoughts but also strengthens their understanding of those concepts (43–45).
- Writing in a mathematical context can strengthen students' conceptual understanding of complex mathematical topics, such as geometry (46).
- Writing allows students to formulate definitions, explain evidence, and articulate relationships between geometric concepts (47).
- Writing can help students develop analytical thinking in geometry. By writing, students are asked to formulate and compile evidence, identify patterns, and explain geometric relationships. This process assists students in developing the ability to analyze problems and find mathematical solutions (44, 47).
- Writing allows students to strengthen connections between geometric concepts. In the writing process, students not only describe geometry visually or verbally, but also decipher mathematical proofs and write the relationship of these concepts to other mathematical contexts (48, 49).
- Writing allows students to reflect and formulate their mathematical reasoning better. In the context of geometry, students can use writing as a tool to plan and evaluate problem-solving strategies, as well as to articulate their thought processes in achieving solutions (50).
- Writing helps students in identifying geometric patterns and structures. In writing about geometry, students can outline observed patterns, group information based on similarities or differences, and infers geometric rules or properties they find (46).

Conclusion

Learning Geometry with the GeoGebra application has a positive influence on improving students' geometry skills compared to learning Geometry without the GeoGebra application. The GeoGebra application provides a very concrete visualization of the delivery of Geometry material, especially students become more motivated. So that students are able to absorb the material optimally. Before being given learning with the GeoGebra application, it is known that geometry skills consist of five indicators, namely visual, verbal, drawing, logic, and applied. Furthermore, after being given learning with the GeoGebra application regularly and based on the results of the analysis of errors made by students in solving geometry skill problems, it was found that writing became an important indicator as part of the benchmark of students' geometry skills. The writing indicator in question is being able to clearly write information and ideas in various perspectives and explain the

geometric problem-solving process plan. This research is expected to be an interactive learning reference that is able to motivate and optimize students' geometry skills during Geometry learning. In the learning process that utilizes the GeoGebra application, it is always accompanied by the demand to keep writing down mathematical ideas and discussion results because it is an important factor in optimizing students' understanding of Geometry material, especially for improving students' geometry skills.

Abbreviations

Not applicable.

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This study was carried out through the collective effort of the authors. Responsibilities encompassed: conceptualizing and designing the study; gathering, analyzing, and interpreting the data; and drafting and revising the manuscript.

Conflict of Interest

There is no conflict of interest in relation to this study from either parties involve.

Ethics Approval

This research did not involve human or animal subjects; therefore, ethics approval is not applicable.

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