INTERNATIONAL JOURNAL OF CONTEMPORARY STUDIES IN EDUCATION
Vol. 03 No. 03 (2024), 269-277

IJCSE

https://journals.eduped.org/index.php/ijcse
E-ISSN 2963-0282
P-ISSN 2963-5993

Errors in Solving Distance Material on Spatial Figures: Analytical Study on High School Students of Bengkulu Tengah

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DOI: https://doi.org/10.56855/ijcse.v3i3.1239
Received July 13, 2024; Accepted September 29, 2024; Available online November 5, 2024

Abstract: Mathematics learning outcomes at the senior high level are still low at the national level. It can be shown that from the result of the Minimum Competence Assessment (MCA) in these two years, the outcome of senior high students is below minimum competence. Problems become the factors of low student competence; one of them is the classroom learning process. In the process of solving that problem, teachers can analyze how students solve the mathematics problems given so the correct method can be figured out. The purpose of this research is to analyze the errors students make when solving questions about spatial figures and the solutions given to solve the errors. This research is qualitative descriptive research. The subjects in this study were 29 students of class XII of Bengkulu Tengah State Senior High School. These subjects were selected based on the tendency of students to make errors in geometry material. Data were collected through geometry test questions and unstructured interviews. Data are analyzed descriptively and qualitatively. The results of the study showed that students made mistakes in solving geometry problems with visualization errors (34.50%), analysis errors (23.54%), and deduction errors (22.54%). The factors causing the errors made by students were: (1) students were less careful in understanding and analyzing problems, (2) students made mistakes in interpreting problems in the form of images, (3) errors in calculations, (4) students were less careful in making conclusions. Based on the results of this study, it is recommended that teachers in delivering geometry material need to emphasize that students visualize problems with images or geometric constructions so that it is easier to solve problems.

Keywords: Analysis, Errors, Geomertry

1. Introduction

Mathematics is a learning process that is taught in schools since elementary school (SD) to high school (SMA). As the basis of many sciences that can differentiate between developed and less developed societies (Susanta et al., 2023). Mathematics has an important role in forming an understanding of abstract and applied concepts in students, especially in geometry subjects (Simamora & Siagian, 2021). Sudihartinih & Mulyana (2014) stated that geometry is a branch of mathematics that must be taught in schools because with geometry, several

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problems in everyday life can be solved. Geometry is also very close to students because several objects around students are also geometric objects (Safrina et al., 2014). It's just that students don't realize that these objects are part of the geometry material. So, it is necessary to emphasize learning in the classroom by introducing the real objects.

Geometry as a branch of mathematics that allows students to develop an understanding of shape, size, and spatial relationships (Ulfah & Felicia, 2019). Walle (Nopriana, 2014) put forward several important reasons for studying geometry, such as: (a) geometry provides a more complete picture of knowledge about the world, (b) exploring geometry can improve problem-solving skills, (c) geometry has an important role in learning other interrelated concepts in mathematics teaching; (d) geometry has been used by people every day without them realizing it (e) geometry is a lesson that can provide pleasure.

Meanwhile, many students face difficulty in understanding Geometry. Pradika and Murwaningtyas (2012) stated that students only memorize formulas but they are unable to use these formulas in solving geometry problems. This is because students do not know the symbols and terms in geometry problems. Ozerem (2012) revealed that common errors which is found are conceptual errors, lack of background knowledge, incorrect reasoning and incorrect basic operations in geometry material. Previous researches data shows that student learning outcomes in geometry are low compared to other content. For example, research conducted by Susanto et al (2021) which states that the results of the analysis of students' abilities in geometry only reached 23.46% with low criteria. So, geometry material needs to be a focus in mathematics learning at the high school level.

Apart from student factors, teachers are also an important role in encouraging students to learn to understand geometry material, both in terms of teaching methods and media or models used. In delivering geometry learning material, teachers need to pay attention to several things such as the level of student ability, student mental development, teacher strategies in compiling geometry teaching materials, and evaluation of student learning outcomes. These things have not been implemented by most teachers, they only focus on the learning process in class and see the final results of students. In teaching mathematics, teachers need to pay attention to the stage of development of student abilities or student thinking levels. To overcome this problem, especially in geometry material, teachers must always understand or follow the flow of students' thinking. The results of research conducted by Sutama, Suharta, and Suweken (2014) state that the characteristics of geometry learning in schools consist of three stages, they are: (1) learning begins with a visualization process through example images on the media, then students explore in order to find concepts; (2) giving examples by students aims to deepen their understanding; and (3) the integration process aims to summarize all student learning experiences. These stages can be applied in the geometry learning process in class.

One method that teachers can use to determine the level of student thinking in learning geometry is Van Hiele's theory. This is in line with Abdussakir (2009), who mentions that geometry learning should pay attention to the level of student thinking with Van Hiele's theory, which pays attention to the stages of students' cognitive development levels (Armah & Kissi, 2019). Therefore, teachers must pay attention to providing geometry learning that is in accordance with the level of student thinking (Lestariyani et al., 2014). Van Hiele's theory provides levels of student geometric thinking sequentially through 5 levels, such as visualization, analysis, informal deduction, deduction, rigor. Geometry is a branch of mathematics that is taught at every level of education, from elementary school to college. The three main elements in geometry learning, according to Van Hiele (Aisyah, 2007) are learning time, learning materials and learning methods. From the description above, researchers are interested in knowing about the level of student thinking in working on questions based on Van Hiele's theory of solving geometry problems.

Efforts are made to improve students' thinking levels in geometry learning by identifying student errors in learning. Many theories can be used to identify student errors in geometry. One of them uses the level of thinking based on van Hiele's theory, namely visualization, analysis, deduction, and rigour. many previous studies have analyzed student errors in learning geometry. errors in geometry can be errors at the transformation stage, errors in understanding questions, errors in writing answers, and process errors (Hartini & Setyaningsih, 2023). The errors in geometric thinking skills, such as visualization, analysis, and abstraction. In this study, the focus of the errors observed were visualization, analysis, and deduction errors with the material on distance in geometric shapes.

2. Method

2.1 Type of Research

This research is qualitative descriptive research. This method aims to examine objects in natural conditions, with the author as the vital instrument (Sugiyono, 2019). Research is used to describe or explain objects systematically, factually, and accurately regarding a fact. This is in accordance with the primary objective of the study, namely to describe students' errors in solving geometry material problems. The focus of the research in this study is to describe students' errors in solving geometry material problems on the sub-material of distance between points, planes, and space.

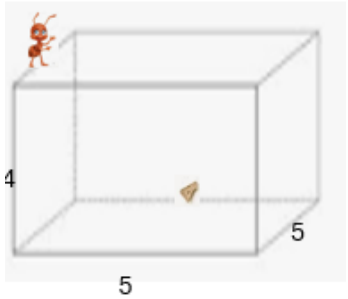
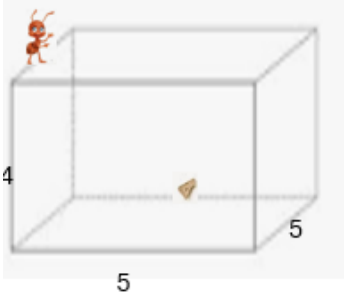
2.2 Target of the research

The target of this study was students of class XII of SMA Negeri 1 Bengkulu Tengah. The selection of subjects for grade XII was based on the students' thinking level, especially in mastering geometry material. This class has studied the material focused on in this study, such as the distance in geometric shapes. The number of subjects in this study was 29 students, consist of 17 female students and 12 male students.

2.3 Data Collecting Technique

The first data collection technique is a test. The test used in this study is a written test with four questions in the form of a description. The material that is the focus of this test is the geometric shape, the distance between points, and the area of the geometric shape. Data collection is also supported by unstructured interviews with the aim of confirming the mistakes made by students. This interview was conducted based on the results or answers given by students. The instrument in this study also went through a content assessment by a mathematics teacher.

The material was first studied using the research instrument in the form of test questions that measure students' geometry abilities, and appropriate indicators were developed. The questions developed have also met expert assessments on material, construction, and language aspects. The results of the expert's study are used as a reference that the questions are theoretically suitable for data collection. In exploring students' errors in solving geometry problems, four questions are designed in the form of understanding (see Figure 1).

Geometry test questions	Translate in english
Di atas meja terdapat sebuah kotak kue berbentuk balok dengan ukuran panjang : lebar : tinggi=5:5:4. Seekor semut tepat berada di tengah-tengah salah satu sisi bagian atas. Di bagian dasar kue terdapat remahan kue seperti pada gambar.	On the table is a cube-shaped cake box with dimensions of length, width, and height=5:5:4. An ant is right in the middle of one of the top sides. There are crumbs at the bottom of the cake, as shown in the picture.
	
Berapa jarak tempuh terpendek yang mungkin dilalui semut menuju remahan kue?	What is the shortest distance an ant can travel to the cookie crumbs?
(a) Soal nomor 1	(a) Question number one
Andri ingin membangun model piramida untuk presentasi. Piramida yang akan dia buat memiliki alas berukuran 60 x 60 cm dan tinggi segitiga piramida 50 cm, berapakah tinggi piramida tersebut?	Andri wants to build a pyramid model for a presentation. The pyramid he will make has a base measuring 60 x 60 cm and a height of the pyramid triangle of 50 cm; how high is the pyramid?
(b) Soal nomor 2	(b) Question number two

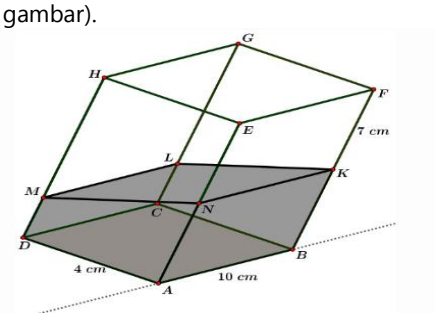
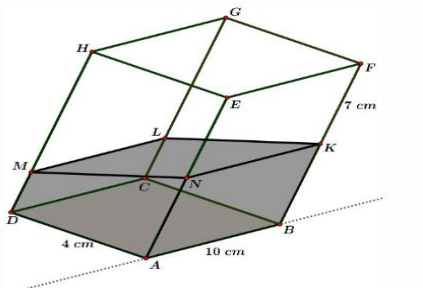
Ke dalam sebuah wadah berbentuk balok berukuran 4 cm×10 cm×14 cm diisi air sebanyak 220 cm3. Kemudian balok tersebut dimiringkan sehingga luas permukaan air dalam wadah semakin besar (lihat gambar).	A cube-shaped container measuring 4 cm × 10 cm × 14 cm is filled with 220 cm3 of water. Then, the cube is tilted so that the surface area of the water in the container becomes more extensive (see picture).
	
Berapakah luas permukaan air saat ini?	What is the surface area of the water now?
(c) Soal nomor 3	(c)Question number three
Sebuah Gedung pertunjukan memiliki ukuran 80m x 40m x 10 m. Di bagian depan terdapat panggung berukuran 20m x 10m x 1m dan ditutup tirai. Jika Andi berada 2 m dari dinding belakang Gedung. Berapa jarak yang harus ditempuh Andi ke panggung agar ia dapat menghias bagian depan panggung?	A performance hall has dimensions of 80m x 40m x 10m. In the front is a stage measuring 20m x 10m x 1m covered by curtains. Suppose Andi is 2 m from the back wall of the building. How far must Andi travel to the stage so that he can decorate the front of the stage?
(d)Soal nomor 4	(c)Question number Four

Fig. 1 – Research instrument (a) question 1; (b) question 2; (c) question 3; (d) question 4

2.4 Data Analysis Technique

The data was analyzed descriptively. It means that student errors in solving geometry problems are described. The analysis of test result data refers to the percentage of student errors at two levels of geometry, such as: visualization errors, analysis errors, and deduction errors. The Interview data was analyzed descriptively to explain the error factors made by students.

3. Result and Discussion

3.1 Description of research implementation

This research was conducted in stages, starting with preparing a test instrument to measure students' abilities in geometry material. The preparation of this instrument was also based on the findings of an initial survey that the mastery of high school students in geometry material was still low. Thus, information was collected regarding student errors in solving. This was done to determine the proper steps in improving learning.

The initial stage of this research is to design a geometry test in the form of a description. This instrument went through a development stage involving expert assessment (lecturers and teachers) with the conclusion that the questions met the criteria for being suitable for use. In addition, the questions were also tested empirically involving 18 grade XI high school students at SMA Negeri 1 Bengkulu Tengah. The empirical test results were analyzed for reliability with the Cronbach alpha test with a value of 0.74 (reliable). Based on these two things, the instrument in this study meets the eligibility criteria for data collection.

In the implementation of the research, the instrument was given to the research target, namely 29 students. The test results were tabulated and analyzed against the errors made by students. In the next stage, we also conducted interviews on the responses given by students in answering the questions.

3.2 Description of Student Work Results

The results of the error analysis on two questions that were tested on the material of point distance in geometric shapes. The results of the analysis of the answers from 29 students in solving the questions (Q) are summarized in the following table.

Table 1 - Results of description of the results of working on the questions

Question Number	Correct	False
Q 1	0 [0.00%]	29 [100.00%]
Q 2	23 [79.32%]	6 [20.68%]
Q 3	24 [82.75]	5 [17.25%]
Q 4	0 [0.00%]	29 [100.00%]

Based on the data in the table above, it shows that for questions number 1 and number 4, none of the students answered correctly. However, for question number 2, there were 23 people (79.32%) and for question number 3, there were 24 people (82.75%) who answered the question correctly. These results need to be explored in depth about how students answer each question. Especially for questions number 1 and 3 which measure common distances in geometric shapes such as height, length in geometric shapes. These questions are already familiar to students in routine questions that are commonly made. Different from questions number 1 and four, students need to construct geometrically and have geometric abilities to solve problems in the questions.

In this study, the focus of the analysis is student errors in geometry material with sub-material on the distance between points in geometric shapes. We describe student errors based on the level of student geometry ability, which consists of visualization, analysis, and deduction. Descriptions of student errors based on level are summarized in Table 2.

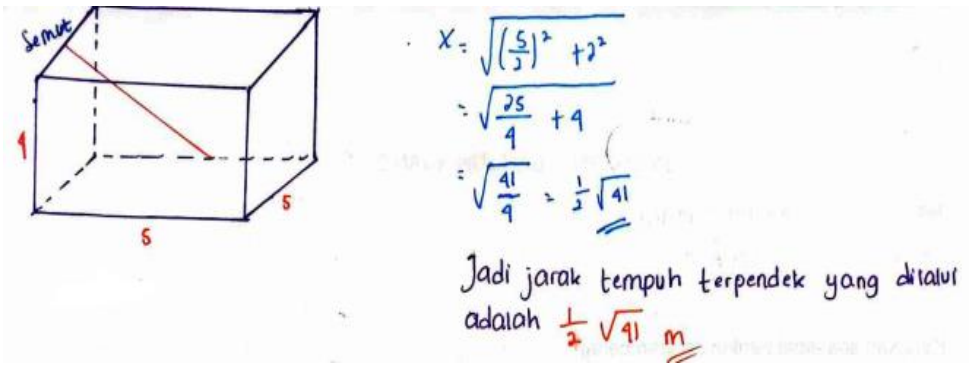
Table 2 - Results of the description of errors in the results of working on the questions

Question	Errors		
	Visualization	Analysis	Deduction
Q 1	18 [62.08%]	29 [100.00%]	29 [100.00%]
Q 2	4 [66.67%]	5 [83.33%]	5 [83.33%]
Q 3	3 [60.00%]	4 [80.00%]	4 [80.00%]
Q 4	20 [86.95%]	23 [100.00%]	23[100.00%]

The data in Table 2 shows that the percentage of students who made mistakes at each level is higher than those who answered correctly. This shows that in general, students have not understood the material.

3.3 Student Error Analysis Results

The results of the analysis show that some students have been able to answer correctly at each level, namely the visualization level, the analysis level, and the deduction level. We present one example of a student's answer that was answered at each stage. One example of a student's answer in solving question number 1 is as shown in Figure 2.



Pic. 2 – Example of student work on question number 1

Based on the results of the analysis above, it can be seen that students have not been able to visualize problems in the form of images. The image above shows that students are wrong in describing the position

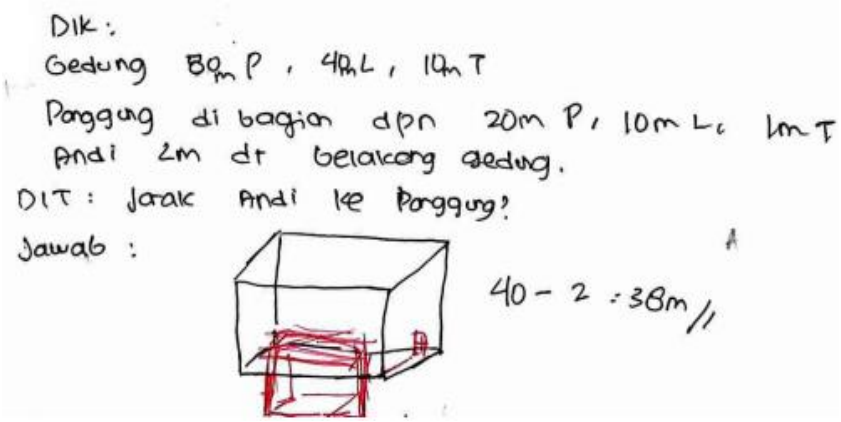
of the ants and the points in question. It can be seen that students misunderstand the concept of distance in space and that ants must pass through a plane.

The translated results of the interview confirmation with students who made mistakes in completing question number 1 are as follows.

Teacher: After you draw the cube, have you correctly depicted the position of the ants?
Student: I have done it, ma'am.
Teacher: Why don't you name the points on the shape?
Student: Forget, ma'am"
Teacher: Is it true that the line you drew is the movement of ants?"
Student: That is the closest distance"
Teacher: Imagine, can ants move? Can they fly?
Student: Cannot, ma'am
Teacher: So ants have to cross the sides of the structure you created."
Student: ok. Maam.

Based on an interview with one of the students, it can be seen that in the visualization, the student was wrong in determining the points of the problem. The student was only able to describe the cube shape but misinterpreted the intended distance. In a real context, ants will move on the plane or sides of the shape. In addition, the student also did not name the points on the cube shape that was made so that it became one of the factors that made it difficult to determine the distance between the intended points.

Furthermore, the results of the analysis of students' answers show that students have not been able to visualize the problem in question correctly. One of the students' answers to question number 4 is shown in the following Figure 3.



Pic. 3 – Example of student work results for question number 3

Errors made by students when solving geometry problems are confirmed through interviews. The purpose is to confirm the location of the errors made by students and the factors causing the errors.

Teacher: Please review your answer!
Student: Yes, ma'am.
Teacher: You have correctly created what is known through the available information, but is the image created appropriate?
Student: Appropriate, ma'am.
Teacher: Why aren't the distances written on the picture?
Student: Still confused, ma'am
Teacher: It is better to write it on the picture, so it is easy to calculate what the question asks.?
Student: Yes, ma'am, I am still confused, ma'am

The information above illustrates that students misunderstand the problem by writing incorrect information. This impacts the visualization stage even though the cube structure has been described. The effect of this error is that students need to be corrected when carrying out the work steps. So, it is essential to emphasize that in solving trigonometry problems, understanding what is known and asked is very important to master. Because the visualization stage of the correct information is vital so that what is constructed geometrically can be made correctly.

The results of confirmation of student errors and error factors through interviews with students as a whole resulted in the following conclusions.

Table 3-Error Analysis Results

Question	Error position	Factors	Solution
Question 1	The logical fallacy, is that ants cannot jump	• Forget that ants do not jump • Not concentrate	The importance of reminding students to understand the questions well
	Error in describing the intended distance	• Incomplete understanding • Unable to visualize	More often, give similar questions
Question 2	Error depicting the height of the pyramid	• Incomplete understanding • Unable to visualize	Use of colored pens/markers for learning
	Mistakes in using the Pythagorean theory formula	• Inadequately learning the definition of formulas	Students should be encouraged to study harder
	Calculation error	• Basic undercount	Students are encouraged to study harder
Question 3	The quadrilateral area is incorrect due to the length of one of the sides being miscalculated.	• Forgot to associate the Pythagorean theorem formula	More frequent reminders in learning
	Operation error while searching for the specified area	Lack of basic arithmetic	More Exercises involving basic arithmetic
Question 4	Unable to visualize the distance referred to in the question	Lack of understanding of the problem	Use of concrete objects in learning/visual aids
	Calculation error	Lack of basic arithmetic	More Practice

Based on the findings of the research results that have been described in general, it can be concluded that students make each error. However, in solving distance problems in geometric shapes, the initial error made by students is visualizing. This error has an impact on the next stage of geometry. Students' mistakes in visualizing have an impact on how students analyze and solve problems. This is in accordance with the results of research by Sutama, Suharta, and Suweken (2014), which states that geometry learning begins with the visualization process in order to understand the concept.

In solving geometry problems, there are many things that teachers pay attention to, one of which is how students understand the problem to create a mathematical model. This is important because solving problems is the primary key that students must master. When students need to understand the meaning of the problem, they will be right in the next stage. However, this study found that some students were correct in the following cognitive stage but needed to write what was known and asked from the problem. Some possibilities occur: first, the student forgot to write the information from the problem but understood it, and second, the student did not understand the problem. Confirmation through interviews obtained information that students needed to remember to write information from the problem. The visualization stage is vital in exploring student errors in solving geometry problems. This is related to how students construct geometrically from the problems given. Making the proper construction will help students solve problems. Geometric construction is essential in solving problems because students can explore more and find which geometric concepts will be used for the solution.

4. Conclusion

Based on the results of the study, it is clear that grade XII students still have errors in visualization, analysis, and deduction in solving spatial figures. The main problem is the lack of thinking and reasoning skills. The implication of the results of this study is as a basis for teachers in the classroom to emphasize learning geometry material with the Van Hiele stages. As a suggestion, teachers must be able to present distance learning on spatial figures with visual aids, and students must be more accustomed to the descriptive questions.

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