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ANALYSIS OF STUDENTS' ERRORS IN SOLVING MATHEMATICS PROBLEMS BASED ON THEIR CONCEPTUAL UNDERSTANDING

Fairun Nisa*[1], Irajuana Haidar[2], Tahir[3]
[1,2,3] Universitas Sembilanbelas November Kolaka

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ABSTRACT

This study aims to describe students' errors in solving mathematics problems based on their conceptual understanding. This research employed a descriptive qualitative approach involving 28 eighth-grade students from SMP Negeri 1 Latambaga. Data were collected using a conceptual understanding test, designed based on several indicators (classifying objects according to their properties, giving examples and non-examples of a concept, applying concepts algorithmically, and presenting concepts in various representative forms). Student errors were analyzed using Nolting's theory, which categorizes errors into careless, concept, application, and test procedure errors. The instrument was validated by mathematics education experts and teachers, and tested for item validity. After the test, four students representing different ability levels (high, medium, low, very low) were selected for interviews. The results showed that, in general, students' conceptual understanding was low. The most dominant errors were concept and application errors, while procedural and careless errors also appeared but less frequently. In conclusion, students' errors are primarily caused by weak conceptual understanding and a lack of systematic problem-solving abilities.

Corresponding Author:

Fairun Nisa,
Departement of Mathematics Education,
Universitas Sembilanbelas November Kolaka, Indonesia
Email: nisafairun125@gmail.com
Phone Number : 082349084106

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1. INTRODUCTION

Education requires a planned and stable system and has clear goals so that the direction to be achieved is easier to realize (Muhammad Haris, 2015). In this case it is in

Indonesia, Law No. 20 of 2003 emphasizes the importance of creating a learning environment that enables students to develop their full potential. In this context, mathematics education played an important role in developing students' logical thinking skills and systematic problem-solving abilities.

In the learning process, especially in mathematics subjects, many students struggle to solve mathematics problems due to a lack of conceptual understanding, misapplication of formulas, and misinterpretation of problems (Permatasari et al., 2023).

In addition, a lack of understanding of systematic problem-solving steps is also a major factor in students' mistakes. Some students immediately attempt to calculate without first analyzing the problem, resulting in incorrect answers. Other errors include the incorrect use of mathematical symbols, improperly structured equations, and a lack of understanding of the units or the final form of the required answer. Conceptual understanding is essential for helping students avoid such errors and solve problems effectively.

Conceptual understanding refers to the students' ability to interpret, represent, and apply mathematical ideas in various contexts (Firjon & Raicudu, 2023). The ability to understand mathematical concepts is also a fundamental skill that students must master in order to solve mathematical problems correctly. Without this understanding, students are prone to making mistakes in the process of solving mathematical problems. Rismen et al. (2021) revealed that students' mistakes in solving problems were usually caused by a lack of understanding of basic mathematical concepts. To identify the types of errors in this study, Nolting's theory was applied. Nolting (2002) classified students' errors into four categories: careless mistakes, conceptual errors, application errors, and test procedure errors. Sukmawati & Amelia (2020) stated that these four types of errors were as shown in Table 1.

Table 1. Nolting Error Indicators

Types of Errors	Indicator
(Careless errors)	Learners carelessly rewrite the components of the given problem before solving the problem, operation signs, and answer results.
(Concept errors)	Learners do not master the mathematical concepts in the problem.
(Application errors)	Learners know the formula but cannot apply it to solve the problem.
(Test prosedure errors)	Learners do not complete the answers to the given problem.

The study used four indicators of conceptual understanding Rosmawati & Sritresna (2021): classifying objects, providing examples and non-examples, applying algorithms, and using multiple representations.

According to observations and interviews with an eighth-grade mathematics teachers at SMP Negeri 1 Latambaga, many students frequently make errors when solving problems. However, no in-depth analysis has been conducted to investigate the specific types and cause of students' errors in solving mathematics problems.

If a student has difficulty solving math problems, it indicates that their understanding of basic concepts is still immature. One of the main factors causing this error is the student's inability to understand the problem well. Research by (Septihani et al., 2020) found that 41.17% of students' errors occurred at the stage of understanding the question, indicating that conceptual understanding greatly influences success in solving mathematical problems. In addition, errors in the use of mathematical symbols and representations also frequently occur. Yuliyanti (2021) revealed that students often make mistakes in using root symbols or drawing geometric shapes correctly, indicating that their understanding of the concepts is still immature. Students' misunderstanding of concepts often becomes an obstacle in their learning process. An incomplete understanding of concepts can lead to various types of errors in solving problems. Previous studies have shown that students have different ways of constructing conceptual understanding, which is influenced by their experiences and how they process information.

From the problems that have been revealed, the researcher thinks that it is necessary to conduct research aimed at finding out student errors in solving math problems. This is important so that teachers and students are able to find out where students make mistakes in solving math problems. Researchers will analyze student errors in solving mathematics problems in terms of the ability to understand mathematical concepts. Based on the background that has been conveyed; therefore this study aims to analyze students' errors in solving mathematics problems based on their conceptual understanding.

2. METHOD

This study employed a descriptive method with a qualitative approach. According to Sugiyono (in Wijaya, 2020) descriptive research is used to analyze data by describing phenomena as they are.

In this study, the primary instrument in this study was the researcher, supported by test questions and unstructured interview guidelines. The test consisted of four questions designed to measure students' conceptual understanding using four indicators: classifying, giving examples/non examples, applying algorithms, and representing concepts and also the Nolting error indicator. The test questions were prepared by the researcher and have gone through a validated by two mathematics education experts and one mathematics teacher. Based on the test results, unstructured interviews were conducted to explore students' errors more deeply. The subjects were eighth-grade students at SMP Negeri 1 Latambaga in the even semester. The research subjects were given mathematics problems to identify their errors in solving problems based on conceptual understanding. Furthermore, based on the test results, four students representing various ability levels were selected for interviews based on the test result.

After analyzing the test as a whole, various values are obtained, which will then be described in the interpretation of the level of ability to understand mathematical concepts according to Istikomah & Jana (2018):

Table 2 Categories of Conceptual Understanding Based on Percentage Scores

Percentage (%)	Category
81-100	Very High
61-80	High
41-60	Medium
21-40	Low
0-20	Very Low

Data analysis in this study involved data reduction, data display, and conclusion drawing. Data validity in this study uses data source triangulation. Data source triangulation was used to validate the findings by comparing various sources, including documents, interviews, and test results. In this research, triangulation of data sources comes from test results and interviews.

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3. RESULTS AND DISCUSSION

3.1 Results

This study aimed to describe students' errors in solving mathematics problems based on their conceptual understanding. The subjects in this study were 28 students of class VIII SMP Negeri 1 Latambaga. Data were collected through conceptual understanding tests and unstructured interviews. The test questions consisted of items on the Pythagorean theorem, selected because it was a basic topic that required strong conceptual understanding. The students' responses were analyzed using Nolting's error indicators and conceptual understanding indicators.

3.1.1 Mathematical Concept Understanding Ability Test Results

The ability to understand mathematical concepts was analyzed using indicators conveyed by Rosmawati & Sritresna (2021) namely (1) Classify objects according to certain properties in accordance with the concept; (2) Provide examples and not examples of a concept that has been learned; (3) Apply concepts algorithmically; (4) Present a concept in various forms of mathematical representation.

The data on the distribution of students based on the ability to understand mathematical concepts is presented in table 3. The table shows that most students were in the low (57.14%), very low (3.57%), and medium (28.57%) categories, with only 10.71% in the high category. The average score was 43, indicating a medium level of conceptual understanding.

Table 3 Mathematical Concept Understanding Ability

Category	Frequency	Percentage
Very High	0	0%
High	3	10.71%
Medium	8	28.57%
Low	16	57.14%
Very Low	1	3.57%

3.1.2 Results of Student Error Analysis

Based on the test results, the researchers analyzed student errors according to each error indicator. Student errors are classified according to error indicators based on Nolting's theory, namely (1) Carelessness errors: students carelessly rewrite the components of the problem given before solving the problem, operation signs, and answer results, (2) Concept errors: students do not master the mathematical concepts in the problem, (3) Application errors: students know the formula but cannot apply it to solve the problem, (4) Test procedure errors: students do not complete the answers to the problem given.

There are 4 indicators of student errors in solving the studied math problems. Careless errors occurred in 35.71% of students (low category); concept errors in 78.57% (high category); application errors in 79.46% (high); and test procedure errors in 55.35% (medium). The overall average percentage of student errors was 62.27%, placing it in the high category.

3.2 Discussion

The data collected from the mathematical concept understanding ability test showed variations in students' abilities. Based on data analysis, it is obtained that there are 4 categories of mathematical concept understanding ability, namely high, medium, low, and very low. One student was in the very low category, 16 in the low category, 8 students in the medium category and 3 students in the high category. From the test results, several student errors were also obtained in solving math problems on each indicator with different percentages of errors, on errors due to carelessness of 35.71%, concept errors of 78.57%, application errors of 79.46%, and test procedure errors of 55.35%. Therefore, from 28 students, 4 students were selected to represent the criteria of the ability to understand ability mathematical concepts and student errors in solving math problems. Based on the results, follow-up interviews were conducted with four selected students. The results of the interviews with the 4 students determine student errors in solving math problems related to the Pythagorean theorem, in addition to tests and observations. Through interviews, researchers can find out the truth and validity of the students' answers.

The first error indicator is errors due to carelessness, which is a type of error made by students due to small mistakes that could have been avoided. Although seemingly trivial, this error can have a significant impact because it can cause the answer to be wrong. Various factors can trigger this error, such as haste and lack of concentration. This is in line with the research of Ulpa et al. (2021) which states that carelessness errors arise because students are less careful and in a hurry when solving problems. An example of this type of error can be seen in Figure 1.

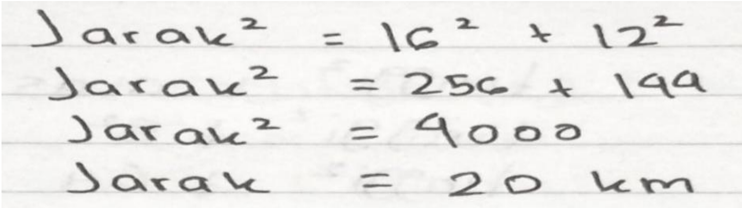

Figure 1. *Careless errors*

In figure 1, it can be seen that the subject was careless in answering the question. The initial step was correct, which was using the Pythagorean formula to find the distance. However, the subject made a mistake in adding the squares of 16^2 and 12^2. It should have been 256 + 144 = 400, but the subject wrote the result as 4000. This caused the next step to be illogical, even though the final result was still written as 20 km. This mistake demonstrated that the student's conceptual understanding remained intact; the error emerged solely from carelessness during the calculation process. To confirm the reason behind this answer, the researcher conducted an interview with S1, and the following is the quotation:

P : Why does the sum of 256 + 144 add up to 4000?

S1 : Sorry, I was less careful because I was in a hurry. The answer should be 400. (translated)

The subject did make mistakes because he was less careful and rushed in calculating. Although he understood the basic concepts, carelessness in calculations caused the solution process to be wrong.

The second error indicator is concept error which is classified as a fairly large error, because students must understand the concept first as an important first step in master the material. This statement is supported by research Arfany & Faradiba (2022) which explains that understanding concepts is one of the main objectives in learning mathematics. Conceptual errors usually arise because students have not understood both the content of the problem and the necessary solution steps. This is reinforced by findings Arfany & Faradiba (2022), which reveals that many students still experience confusion in understanding and answering questions. Examples of conceptual errors can be seen in Figure 2.

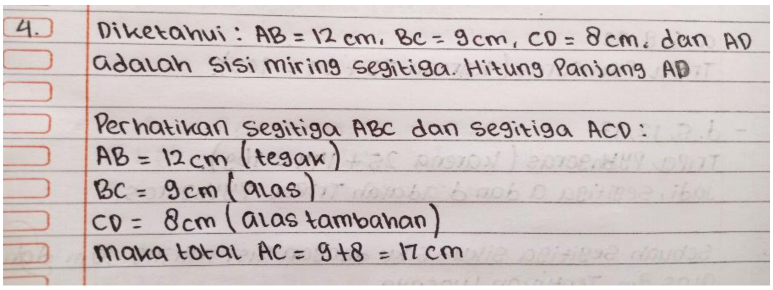

Figure 2. *Concept errors*

In figure 2, it can be seen that the subject made conceptual understanding errors in solving geometry problems, particularly in applying the Pythagorean Theorem. The subject added the lengths of BC and CD directly to calculate AC as 9 + 8 = 17 cm. In fact, based on the actual shape of the triangle, the length of AC should have been calculated using the Pythagorean Theorem because triangle ABC was a right-angled triangle at point B. The correct calculation should have been $AC = \sqrt{AB^2 + BC^2} = \sqrt{12^2 + 9^2} = \sqrt{144 + 81} = \sqrt{225} = 15\ cm$. However, the subject immediately assumed that AC was simply the sum of the two-line segments BC and CD, which was geometrically incorrect. This showed that the student failed to recognize the right-angled triangle structure, which is fundamental for applying the Pythagorean Theorem correctly. As a result of this initial error, all subsequent steps were incorrect, including calculating the length of AD. To ascertain the reason for this mistake, the researcher conducted an interview with S2, and the following is an excerpt of the interview:

P : Why did you add BC and CD to get AC?
S2 : Because I thought that BC and CD were one straight line, so I immediately added them up, sis.

From this excerpt, the subject had misconceptions about the structure of triangles and was wrong in identifying the relationships between points. This error shows a lack of understanding of basic concepts of flat shapes and the Pythagorean theorem.

The third error indicator is application error, students are unable to apply formula into the form of mathematical solution appropriately. Generally, this happens because students only memorize formulas without understanding how to use them in answering problems. This statement is supported by Utami et al. (2023) which suggests that students know the formula, but have not been able to use it to find the answer to the problem given. Examples of application errors can be seen more clearly in Figure 3.

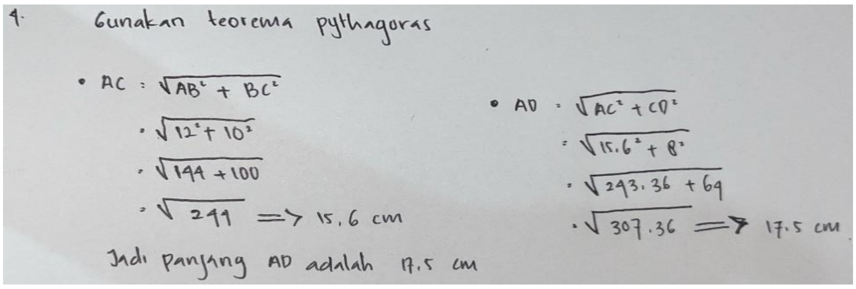

Figure 3. *Application errors*

In figure 3, the subject made a mistake in applying the mathematical form. Although the formula used, namely the Pythagorean theorem, was correct, the subject made a mistake when substituting the value into the formula. The subject wrote the length of BC as 10, even though the problem stated that BC was 9 cm. This error caused the subsequent calculation steps to be incorrect, so the final result was also inaccurate. This mistake indicated that the student relied heavily on memorization without fully understanding the problem context, which often leads to substitution errors. To clarify the cause of the error, the researcher conducted an interview with the subject S3. The excerpt of the interview is as follows:

P : Why did you use 10 for the length of BC?
S3 : Because I saw it in question 10, sis.

From this quote, the subject is wrong in reading or understanding the value that should be used in mathematical form. This show that memorizing the formula is not enough. If students are not able to apply and the formula correctly according to the context of the problem, then the final result will still be wrong.

The last error indicator is test procedure error, students do not display the steps of work systematically according to the procedure that should be. Students immediately write the final result without showing the underlying thought process or calculation stages. This makes it difficult to assess whether the answer is obtained through understanding the concept or simply copying. This error often occurs because students are in a hurry or not used to writing down the procedure completely. This statement is in line with the results of research by Sari (2025) which states that students tend to make procedural errors in solving math problems, namely not writing the sequence of steps for solving even though the final result is correct. This shows that concept understanding is not always in line with good procedural skills. Examples of test procedure errors can be seen more clearly in Figure 4.

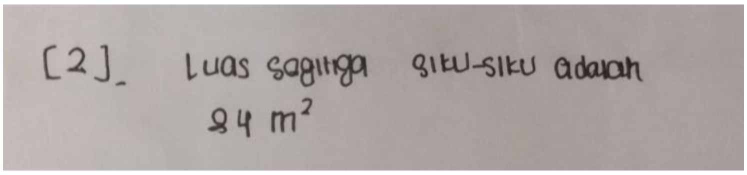

Figure 4. *Test Procedure Error*

In figure 4, it can be seen that the subject made a test procedure error in solving the problem. The subject immediately wrote the final result, namely 24 m^2 without showing the steps of solving or calculating the triangle area formula. In fact, to get these result a calculation process is needed using the formula $L = \frac{1}{2} \times a \times t$ and also using the Pythagorean theorem formula to find the height. The researcher also conducted an interview with S4 to confirm the mistakes made. The following is the quotation:

P : Why don't you write how to do it, just write the final result?

S4 : Because I was sure of the answer, I just wrote the result directly, sis. I don't think it's a problem if I don't write the method.

From the quote, it can be seen that students only write the final result without showing how to solve it. In fact, the steps are important to see if students really understand the problem. Because there are no steps that were taken, the students' answers is considered procedurally incomplete.

Based on the explanation above, it can be seen that the errors made by students in solving Pythagorean theorem problems in terms of their ability to understand mathematical concepts. The results of the data analysis obtained show the types of errors based on Nolting's error indicators and the percentage of error rates in each type of error. Through data analysis and interviews, it was found that S1 made mistakes in the error indicator of carelessness, S2 made mistakes in the consept error indicator, S3 made mistakes in the application error indicator, and S4 made mistakes in the test procedure error indicator.

4. CONCLUSION

The results of this study indicate that students' errors in solving mathematics problems are closely related to their relatively low level of mathematical concept understanding. Students tend to make dominant errors in conceptual and application aspects, indicating a lack of deep understanding of mathematical concepts and their application in problem-solving. Procedural and careless errors were also identified, although with lower frequencies. Interview analysis revealed that each type of error stemmed from different deficiencies in conceptual understanding, including misinterpreting problem structure, applying incorrect formulas, and calculation inaccuracy. This indicates that underdeveloped conceptual understanding is the primary source of various types of errors made by students. Thus, this study provides important insights into students' error patterns and their relationship with conceptual understanding, which can serve as a foundation for enhancing future instructional strategies. This study is limited to one topic (Pythagorean Theorem) and a single school context; further research is recommended to explore different topics and diverse educational settings to confirm the generalizability of these findings.

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