Are students having trouble solving problems polyhedron?

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Abstract The ability to solve problems is not only needed in school learning, but also to solve problems in daily life. One of the problems that cannot be separated from daily life is related to space objects such as tables, cabinets, bottles, balls, houses, and others. Mathematics is a lesson’s school that addresses these problems, especially regarding (to) polyhedrons. The purpose of this study is to describe the difficulties of students in solving problems related to polyhedrons. The difficulties are classified based on Newman’s Error Procedure (NEP). The research method used is a case study. The respondents of this study were middle school students of class IX (ninth grade of middle school). Data collection is done through tests and interviews. Validity is measured based on the Aiken index with a score of 0.82 which mean it is very valid. The difficulties are analyzed descriptively by observing the students’ errors in answering test questions. The results showed that about 8% of students had difficulty in reading error, 13% of students had difficulty in comprehension error, 21% of students had difficulty in transformation error, 49% of students had difficulty process skills error, and 71% of students had difficulty in encode error. It is known several factors that cause these errors so that some solutions can be obtained by the teacher to overcome these errors.

1. Introduction

Problems in everyday life will not be separated from mathematical calculations. Almost all fields are related to mathematics. Examples of common problems in daily life that are closely related to mathematics are the problems of measuring the shape of space. We also live in a space. The objects in a room are also always associated with our daily activities. To be able to solve these problems needed the ability to solve problems. The ability to solve problems should be owned by someone early on. That way problem solving will be based on existing cognitive structures, so there is a high probability of being able to solve the problem.

Problem solving skills can be developed through learning in schools, especially mathematics learning. Gupta explained that the definition of problem solving is as a high-level cognitive process that requires modulation and control skills that are more routine or basic [34]. Problem solving is one of the competencies expected by students after studying mathematics [29]. As said by [24] that mathematical problem solving ability is part of a very important mathematics curriculum, because it can help students develop intellectual skills and work on how to solve problems using problem solving
steps. The ability to solve problems includes the ability to understand problems, plan, carry out plans, and recheck [15]. Almost all mathematical material using problem solving abilities. However, students' problem solving abilities are still low in terms of students' difficulty in answering problem solving questions, especially in the problem description. According to the results of the study [18], students do not experience significant difficulties in solving problems in the form of multiple choice questions, but students have difficulty in solving problems in the form of essay questions. One of them is the material geometry. Learning geometry can train students' problem solving skills and facilitate a variety of other math and science topics [32]. One of the geometry material in particular solid figure, in school is polyhedron.

Solid figure is a part of space that is limited by a set of points found on the entire surface of the building [32]. Whereas according to [25] the construction of polyhedron is a part of geometry that focuses on students' problem solving abilities to identify properties, elements, and determine volume. When solving the problem of constructing flat side spaces or geometry problems, according to Van Hiele [26] students go through the stages of understanding geometry, namely the introduction stage, the analysis stage, the sequencing stage (informal deduction), the formal deduction stage, and the accuracy stage. Students will be more familiar with geometry material if they are familiarized with geometrical shapes that are related to the shapes of goods or buildings around the neighborhood [27].

However, based on [13] very intense learning about flat fields at the elementary school level results in misconceptions and misunderstanding of terms in the construction of polyhedron. In addition, polyhedron is one of the mathematical objects, according to [6] most of the mathematical objects are abstract and difficult to imagine so many students have difficulty imagining them. Learning about the volume or surface area formula in elementary schools is only given directly and memorized. The process of discovering the formulas by itself is not introduced so learning is less meaningful and makes it difficult for students to understand or remember the formulas. The learning method used by the teacher is only in the form of lectures. Occasionally the teacher brings teaching aids in the form of a block or cube model but students are not involved to practice directly in understanding the elements of blocks or cubes. Learning that takes place also has not been linked to everyday life. Similarly, based on research from [9] some of the causes of polyhedron material experience fluctuating changes, because the material presented is still abstract and delivered with lecture methods so learning is less interesting.

According to [37] instilling the concept of material to polyhedron, especially the volume of polyhedron, in junior high school students is not easy because the measurements are abstract. Understanding of student geometry is still very weak despite being given more guidance compared to other material, this is shown from students' complaints when faced with the matter of the area and volume of building space [27]. Based on [12] geometric learning experiences at the previous school level also became one of the factors that caused students difficulties in learning geometry. As the results of research from [21] which states that at the elementary school level students still have difficulty in the area of plane material which is the basis of polyhedron material. It can be seen that students still find it difficult to solve problems related to building flat side spaces. Difficulties experienced by students can be seen from the mistakes made by students when solving the problem of polyhedron. Error analysis can be done by the Newman procedure [4]. Based on [5] Newman argues that students' mistakes in completing mathematical problems include reading errors, comprehension errors, transformation errors, processing skills error, and encode errors. Related to this, this study aims to describe the difficulties of students based on the Newman error analysis procedure in solving problems related to polyhedron.

2. Method
This research uses case study research with quantitative and qualitative approaches. The case study approach was chosen so that it can know in depth and detail about a problem or phenomenon that will be examined [19]. The phenomenon under study is the difficulty of students in solving the problem of the polyhedron using Newman's difficulty analysis procedure. Analysis includes reading
errors, comprehension errors, transformation errors, process skills errors, and encode errors. Each error is described independently.

The subjects were junior high school students class IX SMP Negeri 2 Lumir academic year 2019/2020 amounted to 32 students. The research subjects were chosen based on the consideration and direction of the grade IX mathematics teacher. The research subjects are assumed to have studied material to polyhedron.

Data collected through tests. The test questions are in the form of description questions to find out the difficulty of solving the problem of polyhedron. The test consisted of 5 questions that contained material about cubes, cuboid, prisms, pyramid, and the combinations. The validity of the test was carried out by 3 experts with analysis using the Aiken index [19]. Based on [20] the results of the validity of the coefficient calculation using the Aiken formula will be more stable. Aiken's validity score of 0.82 which means it is very valid. Data analysis was carried out quantitatively and qualitatively. Quantitative analysis is used to determine the percentage of each error based on students' test answers regarding the construction of polyhedron. Whereas qualitative analysis is used to identify forms of error based on Newman’s error analysis. Stages of analyzing data include giving a score on students' answers, classifying errors based on Newman error analysis procedures, calculating the percentage of students in each classification of errors, and conducting qualitative analysis in the form of describing each student's mistakes. In each question students can make more than one mistake. Then for each error in a particular problem a percentage of the number of students who made a mistake will be calculated.

3. Result and Discussion

3.1 Result

Data of students' difficulties in solving problems of polyhedron geometry were identified using the Newman error analysis procedure. The amount of data of students who answered correctly and did not answer was also added. Data analysis is shown in the following Table 1.

| Problem Number | Problem 1 | Problem 2 | Problem 3 | Problem 4 | Problem 5 | Average Percentage |
|----------------|-----------|-----------|-----------|-----------|-----------|--------------------|
| Correct answer | 20        | 63%       | 15        | 47%       | 2         | 6%                 | 10      | 31%       | 0          | 0%        | 29%       |
| Not answer     | 1         | 3%        | 0         | 0%        | 2         | 6%                 | 1       | 3%        | 4          | 13%       | 5%        |
| Reading errors | 3         | 9%        | 0         | 0%        | 3         | 9%                 | 2       | 6%        | 5          | 16%       | 8%        |
| Comprehension errors | 7 | 22% | 1 | 3% | 4 | 13% | 2 | 6% | 8 | 25% | 13% |
| Transformation errors | 6 | 19% | 7 | 22% | 8 | 25% | 3 | 9% | 10 | 31% | 21% |
| Process skills error | 11 | 34% | 14 | 44% | 16 | 50% | 17 | 53% | 20 | 63% | 49% |
| Encode errors   | 14        | 44%       | 16        | 50%       | 30        | 94%                | 22      | 69%       | 32         | 100%      | 71%       |

Table 1. provides information that students have difficulty in solving problems, seen from the average percentage of students answering correctly only 29% or the percentage is very low because it is still below 50%. Even though the percentage of the number of students who did not answer the question was only 5%. This still indicates that students have difficulty in solving the problem of polyhedron. The highest number of students who make mistakes in understanding the problem is in problem number 5 with a percentage of 25%. Likewise with the problem transformation error, process skills error, and encode errors, the number of students who made the most mistakes is in problem number 5. Next, the types of mistakes made by students when resolving the problem of polyhedron are explained.

3.1.1 Reading errors
This error is a student’s mistake in finding meaning from difficult words, sentences, or terms in the problem. Reading error have obtained very small percentage because the test is performed on class IX ability to read mathematical terms is enough. It can be seen from the results of the percentage of students who make this mistake which is not up to 10%.

3.1.2 Comprehension errors

Comprehension errors made by students when unable to find anything that is known and asked in the problem. Or in other words students are able to read the problem but do not know what problem to solve. This error is marked by students not writing down important information contained in the problem. Problem number 1 is "A cube shaped water reservoir has a side length of 1 meter. The water reservoir will be filled with water using a conductor that can hold 20 liters of water. On how much is the water reservoir filled?". In Figure 1.a. students do not know how long the side of the cube is and do not know what exactly the problem will be solved, even though the student already knows the formula of the volume of the cube that should be sought. Meanwhile, problem number 4 is to determine the ratio of 2 volumes of regular rectangular pyramid in which the second marble has a height and a pedestal length twice the first marble with a height of 20 cm and a base length of 12 cm. In Figure 1.b. students do not know what is known in the problem because it only multiplies the number that is known in the problem and does not know what the problem must be solved because students only provide conclusion answers that are far from discussing the results of the volume ratio of the pyramid. This strongly indicates that students have difficulty in understanding problems solving the problem of polyhedron.

3.1.3 Transformation errors

Transformation errors are mistakes made by students who already know what is known and asked in the problem, but do not know what approach, operation, or mathematical formula should be used to solve the problem. Problem number 2 is "Office space in the form of beams with a length of 6 meters, width of 3 meters, and height of 2 meters. The walls of the office will be painted. Every 4 m² wall requires 1 kg of paint. Calculate how many kg of paint is needed to paint the office space". In Figure 2.a. students look for the beam surface area but use the formula to find the beam volume. Because
students enter the wrong formula, students get the wrong solution too. Meanwhile, question number 5 is "Alas a square-shaped tent with a side length of 4 m and height of the tent 7 meters. If the bottom (tent floor) is not covered with cloth, determine the minimum fabric area to make the tent" in the problem added the intended tent illustration. Based on Figure 2.b, students only calculate the surface area of a cube and the area of a triangle, students should calculate the surface area of a triangular prism without one vertical side. The description indicates that students made a mistake in choosing a problem solving plan which means students are still having trouble transforming the problem solving problem to polyhedron.

![image](a)

![image](b)

**Figure 2. Example of transformation error**

3.1.4 **Process skills error**

Process skills error is a mistake made by students when the calculation process. Students are able to choose the necessary mathematical operations, but students cannot run procedures correctly. This error is characterized by errors implementing the formula, errors in mathematical calculations, and errors in the problem solving process. In Figure 3.a, mistakes made by students in the form of errors implementing the formula. Students make the length of the base a broad base. The base area should be \( \text{base length} \times \text{base length} \). From this it appears that students are still not mastered the elements contained in the formula used, making it difficult in the process of solving problems that result in errors in getting the right solution. While in Figure 3.b, the errors of students in the form of error mathematical calculations, \( 12 + 8\sqrt{13} \neq 20\sqrt{13} \). This shows that students have not mastered the sum of rooted numbers which has an impact on problem solving solutions that have not been right. These errors indicate that students are still having difficulty in processing the polyhedron process, especially in implementing mathematical formulas and calculations.
Encode Errors

Encode errors are mistakes made by students in concluding the problem that has been done. Problem number 3 is "A swimming pool measuring 50 meters long and 24 meters wide. The depth of the pool in the shallow part is 1 meter and sloping down to the deepest part which is 3 meters. Make a sketch of the building space of the problem. If the pool is full of water, check whether the water volume = 2,400 liters, explain your answer". In Figure 4.a, the students' mistakes lie in the conclusions fooled in the questions. The volume of water to the full pool should be 2400 m$^3$ not 2400 liters, because 1 liter = 1 dm$^3$. Almost all students make the same mistakes. This indicates that students are still fooled in determining the conclusion of the answer. While in Figure 4.b, mistakes students forget concludes the questions asked at the beginning of the work. Students should combine
all the surface areas that have been sought to find out the area of fabric needed in making tents. These mistakes indicate students are still having difficulty in concluding or writing the final answer as a determinant of the solution obtained.

![Figure 4. Examples of encode errors](image)

3.2 Discussion

Based on the results of data analysis, the mistakes made by students in solving the problem of waking up the polyhedron in the form of reading errors, comprehension errors, transformation errors, process skills error, and encode errors. As for reading errors made by a small proportion of students. This result is in line with the results of Newman's (1997) study which states that there are errors that are not encountered when students solve problem problems, namely reading errors [5]. The results of the study of [31] also showed that the percentage included in the low category in reading errors was 5%. Supported also by research [2], the results of analysis of errors in students shows that the number
of students who make reading errors is only 5% of the total students. These mistakes were made at least by students compared to other mistakes. This indicates that most students have been able to read math problems correctly. With another says, students are able to interpret the words, phrases, or terms that are difficult in the matter.

However, for a small proportion of students who make reading errors, they have difficulty interpreting words, sentences, or terms in the problem. [1] states that one of the difficulties students have in solving problems is the difficulty in reading mathematical problems. The factor that causes it is that students tend to only be able to directly read mathematical material in books but are unable to understand what they are reading. Supported by research from [14] which states that students have difficulty in reading and understanding problems with mathematical language. One of the tendencies of students' mistakes in the language aspect when solving mathematical problems in the form of stories is that students are not able to read the questions correctly, resulting in misinterpretations [7]. Difficulty reading occurs when the problem being read cannot be imagined in students' memories [8]. The solution to find out and then overcome students' difficulties in reading mathematical problems is by asking students to read math problems aloud and then asking students to interpret per sentence [1]. In line with the opinion of [8] which states that students are asked to read aloud the problems in the test, they have a high level of success on the test results. In addition, according to [7], students must have semantic knowledge so that they can interpret the purpose of the problem and analyze all problems. Improving calculation skills can be a solution to reading errors and is highly recommended as a learning strategy [8].

The most mistakes made by students were process skills error and encode errors. The process skills error made by students mainly in implementing mathematical formulas and calculations. In research [3] also describes that the most frequent process skills errors made by students from various levels of class when solving mathematical problems. The factors that cause these errors are reading errors, transformation errors, and carelessness in calculations. This opinion is also supported by research [22] which states that the percentage of students who make process skill errors as much as 23.91 %, which ranks second most of the mistakes made by students. The factors that cause this are low ability students so they do not have a strategy to solve problems and cannot identify mathematical operations. Research [28] also states that one of the students' mistakes in solving mathematical problems is a mistake in the transformation in the form of using a formula or procedure that is not appropriate and does not know what formula is used. In addition, students are also negligent and careless in doing calculations. As the results of research [17] which shows that students are still doing carelessness in counting and manipulating algebraic operations. Based on these error factors, according to [36] there are several actions that can be taken by teachers to prevent and correct mistakes, namely: (a) pay attention to students' basic knowledge when teaching new learning, (b) take clear and specific steps, (c) carefully analyze the causes of errors to immediately correct and let students do the same exercise, and (d) regularly review, consolidate, and systematize students' knowledge and skills in solving mathematical word problems.

Encode errors becomes the most common mistake made by students. That is because this error becomes the final error that can automatically occur if the process of solving the problem before the error occurs. This can also be seen from the results of the study [30] which states that students with low, medium, or high problem solving abilities, all experience encode errors. In addition, from the cognitive side of students, students with a field dependent cognitive style and field independent cognitive style all encode errors [33]. Factors that influence the occurrence of encode errors are students not accustomed to writing answers accompanied by final conclusions. In addition, based on [23] the factors that cause many students to encode errors are errors in the previous step such as reading errors, comprehension errors, transformation errors, and process skill errors. Encode errors can be reduced by doing more exercises and checking answers when finished doing the exercise [23]. In the transformation errors, students are still wrong in choosing the right formula to solve the problem given. This shows the still weak understanding concept in most students. It was also mentioned by [23], the transformation errors is found on every number worked by students. A transformation errors
indicates that the student does not understand the formula well. Because students only memorize the formula but do not understand it. This is also shown by research [11] which states that students still have difficulty in applying concepts or in other words difficulties in applying formulas when solving mathematical problems in the form of story problems.

Comprehension errors is also a standard students difficulty in solving the problem of the polyhedron. This error is seen from students writing down information that is known and asked of the problem or not. Most students write down the identification of their information and asked the question briefly and unclear. This can make students difficult when finding difficult problems. Because students only slightly understand by writing information that is known and asked very briefly. The results of the study of [22] states that the percentage of students who made comprehension errors was 17.39%, having the second smallest number of students who made mistakes like the results of this study. Factors that cause the errors that students are not able to absorb the information properly. The number of students who do not answer the question has a small percentage. Students still write down what they understood of the matter though briefly and yet so clear. [35] provides a solution to overcome these mistakes by using Learning Therapy in the form of group learning to understand the meaning of the problem and reproduce the practice of solving certain problems in detail, correct, and meaningful. Based on the description of students' mistakes in solving polyhedron problems, the teacher can help students to reduce mistakes made by looking at the factors that cause these errors and applying student centered learning. Based on [10], student-centered learning will improve student achievement. In addition, there are errors of understanding because students have difficulty in understanding the problem. According to [16] if students have difficulty in understanding the problem, the teacher can provide scaffolding in the form of directed questions.

4. Conclusions

In general, the difficulty experienced by students in solving the problem of polyhedron is encode errors. Errors occur because of previous errors in the process of solving problems. The second most mistake is the processing skills error which includes errors in implementing math and math calculation errors. Furthermore transformation errors include errors in choosing the right formula due to poor understanding of student concepts. Comprehension errors also affects the students do not write down the important information contained in the problem, both known and asked. A small number of errors also occur in reading errors the meaning of the problem. Those difficulties inconveniences caused by many factors, among which failed to interpret when reading the questions, the ability of students is low, negligence, carelessness in the calculation, the students are not accustomed to write down the answers along with the final conclusion, the occurrence of errors in the previous step when work on the problems, students only memorizes formulas but does not understand the concepts, and students are not able to absorb information properly. The role of the teacher is very influential to reduce the difficulty of students in solving the problem of polyhedron. The teacher can (1) ask students to read math problems aloud then ask students to interpret per sentence, (2) pay attention to students' basic knowledge when teaching new learning, (3) make clear and specific problem solving steps, (4) analyze carefully the cause of the error to immediately correct and let students do the same exercise, (5) regularly carry out reviews, consolidations, and systematize students' knowledge and skills in solving math word problems, (6) give students more practice and recommend checking the answers when finished doing the exercises, and (7) doing Learning Therapy in the form of group learning to understand the meaning of the problem and reproduce the practice of solving certain problems in detail, correct, and meaningful.

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