Analysis of Students' Conceptual Understanding Ability on the Material on Polyhedral Shapes

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Abstract
This study aims to analyze the level of students' understanding of mathematical concepts systematically. The research sample consisted of thirty ninth-grade studentsof SMP Muhammadiyah 3 Bandar Lampung who were selected through purposive sampling technique. This study employs a quantitative approach, utilizing standardized tests and statistical analysis to measure and analyze the phenomenon in depth. The data used in this study include quantitative data in the form of test results that measure the level of students' understanding of mathematical concepts. Based on the results of the analysis and discussion, it was found that the level of students' understanding of mathematical concepts was still in the low category.
Keywords: conceptual understanding, polyhedral shapes, mathematics

Introduction

Mathematics is a discipline that plays a fundamental role in various aspects of life. As a branch of science, mathematics has a significant contribution in forming and developing competent human resources. The competencies in question include analytical skills, interpersonal competencies, decision-making skills, information processing skills, and adaptation to change (Yudha, 2019) . One way to develop mathematical competencies in HR is through the learning process in schools. However, in reality, many students have difficulty learning mathematics because it is considered an abstract and complex science, which has an impact on their low learning motivation (Fitria et al., 2019).

The success of student learning in schools is highly dependent on the success of individuals in understanding and applying the concepts learned. This learning success is influenced by both internal and external factors (Purwanto & Wulanningtyas, 2023) . Internal factors include psychological and cognitive aspects of students, such as interest in learning, intrinsic motivation, talent, and their perceptions of subjects and teaching staff. Meanwhile, external factors include the learning environment, family conditions, socio-economic status, and parental support in helping children face learning difficulties. Low motivation to learn mathematics has implications for the underdevelopment of various competencies needed to understand mathematical concepts comprehensively (Marzuki Ahmad, Rohani, 2022) . The results of previous studies show that the level of

understanding of students' mathematical concepts is still in the low category (Fadhilah Ammar et al., 2024; (Marcha & Zulkarnaen, 2024; Alzanatul Umam & Zulkarnaen, 2022) .

Conceptual understanding is the main foundation in the mathematics learning process. To achieve optimal understanding, mathematics learning must be designed in such a way that allows students to construct mathematical concepts independently (Siti Mawaddah, 2016) . Thus, students do not only receive information passively, but also actively participate in the learning process. The ability to understand concepts well will help students apply mathematics in everyday life, solve problems, and connect concepts that have been learned with previous experiences. Conversely, if conceptual understanding is less than optimal, students will have difficulty applying the concept in problem solving. The importance of understanding mathematical concepts is reflected in the main objectives of mathematics learning, as stated by (Ariyanto et al., 2019) , namely so that students are able to understand mathematical concepts, explain relationships between concepts, and apply concepts or algorithms flexibly, accurately, efficiently, and appropriately in solving problems. Therefore, after going through the learning process, students are expected to have adequate conceptual understanding so that they can use these abilities to face various mathematical challenges.

One of the important topics that has challenges in learning mathematics is polyhedral shapes, which include cubes, cuboids, prisms, and pyramids. Understanding the concept of polyhedral shapes is very important because it is closely related to spatial skills and mathematical visualization abilities. Analysis of conceptual understanding in polyhedral shapes can be done by measuring the extent to which students can recognize the characteristics of each geometric shape, understand the relationship between geometric elements such as edges, sides, and vertices, and are able to apply surface area and volume formulas correctly.

The importance of conceptual understanding in mathematics learning requires an in-depth analysis of students' conceptual understanding abilities. This analysis aims to identify factors that influence mathematical conceptual understanding and find solutions that can be applied in the learning process. By conducting a comprehensive analysis, educators can determine the right strategy to improve the quality of students' mathematical conceptual understanding. Several aspects that need to be analyzed in mathematical conceptual understanding include the ability to connect concepts, apply concepts in problem solving, and the level of flexibility and efficiency in using mathematical concepts.

Thus, this analysis will provide a clear picture of the condition of students' conceptual understanding and the steps that need to be taken to improve it.

Method

This study employs a quantitative approach, utilizing standardized tests and statistical analysis to measure and analyze the phenomenon in depth. Quantitative research is a structured investigation that quantifies data to allow for generalization (Winarni, 2021). . This study aims to analyze the mathematical concept understanding ability of class IX students of SMP Muhammadiyah 3 Bandar Lampung, especially on the material of flat-sided spatial figures. The research subjects were selected using a purposive sampling technique, namely by considering certain characteristics that are relevant to the research objectives. In this case, as many as 30 students from class IX of SMP Muhammadiyah 3 Bandar Lampung were determined as research subjects based on recommendations from the mathematics teacher who taught in the class.

Data collection was conducted by administering an essay test consisting of five questions on conceptual understanding of polyhedral shapes. The indicators of conceptual understanding in this study refer to Jane Kilpatrick, Findell & Swafford (2001) , namely restating mathematical concepts in one's own language, providing examples and non-examples of a concept, classifying objects- object mathematics, presenting concepts with various forms of mathematical representation, and developing the necessary and sufficient conditions for a concept. The scoring criteria for students' mathematical concept understanding abilities after being modified from Siti Mawaddah (2016) can be seen in table 1.

The data analysis method in this study includes three main stages, namely data reduction, data presentation, and drawing conclusions. In the data reduction stage, the researcher analyzes students' answers to obtain relevant information. Furthermore, the results of the analysis are presented in the form of images, tables, and narrative texts to facilitate understanding. In the final stage, the researcher summarizes and concludes all the data and findings that have been collected.

Table 1. Scoring Criteria for Indicators of Understanding the Concept of Flat-Sided Space Structures

Conceptual Understanding Indicators	Criteria	Score
The ability to verbally restate concepts that have been learned	Explains completely and correctly, including the main characteristics of polyhedral shapes	3
	Explains fairly well but lacks detail or has a few conceptual errors	2
	Explains incompletely or contains several conceptual errors	1
	Did not answer or the answer is completely wrong	0
Ability to provide examples and counterexamples of concepts that have been learned	Identify all polyhedral shapes in the image correctly	3
	Identified most of the polyhedral shapes but there was one mistake	2
	Only mention one or two polyhedral shapes correctly	1
	Misidentification or failure to answer	0
The ability to classify objects based on whether or not the requirements that form the concept are met.	Write all the elements of polyhedral shapes correctly	3
	There are one or two errors in the number of elements.	2
	Just write some components correctly	1
	All answers are wrong	0
The ability to present concepts in various forms of mathematical representation.	The image is correct, according to the size given	3
	The image is quite correct but there are slight errors in proportions or size.	2
	Image is not appropriate or has significant errors	1
	No drawing or drawing is completely inappropriate	0
The ability to develop necessary and sufficient conditions for a concept	Answer with correct and complete calculations and provide alternative examples.	3
	Answer with correct calculations but do not provide other examples	2
	Answering with incomplete calculations or misconceptions	1
	Not answering or giving a completely irrelevant answer	0

The method for calculating the level of conceptual understanding achieved by students can be formulated as follows:

$$P = \frac{\text{students' answer scores}}{maximum\ score} x100\% \quad (1)$$

with P as the percentage of student answer scores.

Furthermore, the ability to understand mathematical concepts can be qualified as follows:

Table 2. Percentage Classification Based on Score

Percentage	Classification
0%-34%	Very Low
35%-54%	Low
55%-64%	Currently
65%-84%	Tall
85%-100%	Very high

(Siti Mawaddah, 2016)

Results and Discussion

This study produced data on student learning achievement obtained through a test instrument in the form of five descriptive questions. The test data was analyzed based on scoring guidelines that refer to indicators of mathematical concept understanding ability. Furthermore, the results of the data analysis are presented in the form of percentages to provide a comprehensive picture of student achievement according to the indicators of mathematical concept understanding. The following is the percentage of students' mathematical concept understanding ability:

Table 3. Results of the percentage of students' mathematical concept understanding abilities

Students' Mathematical Concept Understanding Ability		
Number of Students	**Presentation**	**Category**
10	33%	Tall
9	30%	Currently
11	36%	Low

Based on table 3, of the 30 students, the percentage of students who have not achieved the criteria for mathematical concept understanding completion is 66%. The use of category thresholds in this study refers to the criteria established by Siti Mawaddah (2016) . Based on the distribution of learning outcomes, 66% of students (30% in the“Currently” category and 36% in the“Low”category) have not yet reached the“High”proficiency level (≥ 65%), while 63% of students (33% in the“High”category and 30% in the“Currently”category) have achieved at least the“Sufficient”level (≥ 55%). These figures were calculated by dividing the number of students in each category by the total sample size (N=30) and multiplying by 100%. Scientifically, this distribution indicates that although the majority (63%) have attained a minimum level of conceptual understanding, a substantial gap (37%) remains. This highlights the need for targeted intervention to help students in the “Currently” category progress to the “High” level and to reduce the proportion of students performing at the “Low” level. This means that most students do not have good mathematical concept understanding skills. Furthermore, the analysis of the percentage of students' mathematical concept understanding for each indicator is presented in the following table:

Table 4. Percentage Results of Students' Mathematical Concept Understanding

No Question	Mathematical Concept Understanding Indicators	Percentage of Indicator Achievement
1	Restate mathematical concepts in your own words	77%
2	Providing examples and non-examples of a concept	60%
3	Classifying mathematical objects	47%
4	Presenting concepts with various forms of mathematical representation	52%
5	Developing necessary and sufficient conditions for a concept	54%

Based on Table 4. it is known that students are able to restate mathematical concepts in their own language by 77% (with a high category) falls within the “High” range (65–84%), showing most students can verbally articulate definitions. Restating concepts. This likely reflects the relative ease of memorizing and paraphrasing definitions compared to applying them in problem contexts (Bloom et al., 1956), students are able to provide examples and non-examples of a concept by 60% (with a sufficient category) meets the “Sufficient” threshold (55–64%), indicating moderate skill in distinguishing examples, students classify mathematical objects by 47% (with a low category) within the “Low” bracket (35–54%), revealing difficulty in identifying edges, vertices, and diagonals. Classification of geometric objects demands an accurate understanding of their fundamental properties-edges, faces, and vertices-as well as the ability to distinguish between space diagonals and plane diagonals. Many students have yet to master these concepts, often confusing the terms “height” and “length” when their visual proportions appear similar (Karaca, 2023), students are able to present concepts with various forms of mathematical representation by 52% (with a low category) also “Low,” suggesting students struggle with accurate spatial drawing and proportionality, and students are able to develop necessary and sufficient conditions for a concept by 54% (with a low category) at the upper end of “Low,” showing some procedural skill but limited conceptual reasoning. These results indicate that there are several indicators of students' understanding of mathematical concepts that are still in the low category. The following are the results of the analysis of indicators of students' understanding of mathematical concepts that are included in the low category including indicators of classifying mathematical objects in question no. 3, presenting concepts with various forms of mathematical representation in question no. 4 and developing necessary and sufficient conditions for a concept in question no. 5 .

In question number 3 with the following question: "Determine the number of sides, edges, corner points, space diagonals, plane diagonals of the following geometric shapes and their elements."

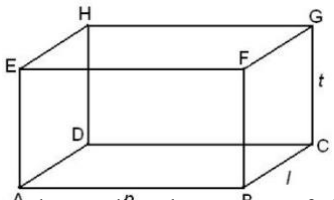

Figure 1. Questions on indicators of understanding the concept of classifying mathematical objects

In question number 3, out of 30 students, a score of 42 was obtained from the maximum score of 90, so that the percentage obtained was 47%, therefore the indicator of understanding the concept of classifying mathematical objects can be said to be still low. In this question, students are asked to determine the number of sides, edges, vertices, space diagonals, and plane diagonals of a given geometric figure and its elements. This question aims to measure the indicator of understanding the concept of classifying mathematical objects based on certain properties. In this case, students are expected to be able to recognize the characteristics of geometric figures, understand the relationships between elements, and apply basic geometric concepts in determining the number of sides, edges, vertices, space diagonals, and plane diagonals. The following is an example of a student's answer to question number 3 which received a score of 1 on a scale of 0 to 3.

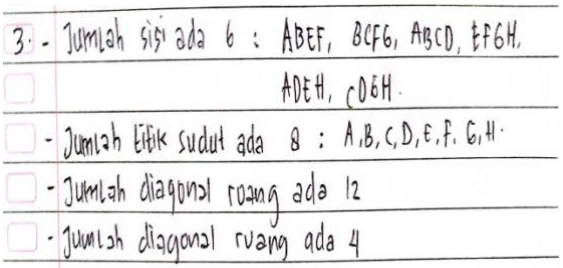

Figure 2. Student Answers with Moderate Concept Understanding

Based on the students' answers above, it can be seen that students cannot identify the given geometric shapes correctly. Mentioning the number of sides, ribs, and vertices randomly or incorrectly. Not understanding the difference between space diagonals and plane diagonals, so that the answers given do not match the characteristics of the geometric shapes. Tend to only guess the answer without showing a logical process or thinking in determining the elements of the geometric shapes.

From the results of the analysis, it can be concluded that students' conceptual understanding in classifying mathematical objects in the material of flat-sided spatial figures is still low. The most common error is in determining the diagonal of space and the

diagonal of the plane, which shows that students do not fully understand the difference between the two concepts.

In question number 3 with the following question: " Draw a rectangular prism with a height of 12 cm, a width of 4 cm, and a length of 6 cm! Explain the properties of the shape! Apart from a rectangular prism, are there any other shapes that have a volume calculated in the same way? Explain!"

In question number 4, out of 30 students, a score of 47 was obtained from the maximum score of 90, so that the percentage obtained was 52%, therefore the indicator of understanding the concept of classifying mathematical objects can be said to be still low. This question aims to measure students' ability to understand and represent the shape of a rectangular prism visually and identify its geometric properties. By completing this question, students are expected to be able to draw a rectangular prism with the appropriate size, understand and explain its constituent elements, such as the number of sides, edges, vertices, and the relationship between the elements of the shape. In addition, this question also aims to train students' spatial skills in visualizing and analyzing the characteristics of spatial shapes systematically. The following is an example of a student's answer to question number 4 which received a score of 1 on a scale of 0 to 3

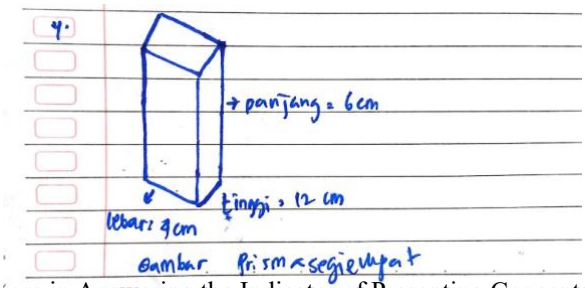

Figure 3. Students' Errors in Answering the Indicator of Presenting Concepts with Various Forms of Mathematical Representation

Based on the students' answers above, it can be seen that students still have difficulty in identifying and distinguishing the main dimensions of a rectangular prism, namely length, width, and height. A common conceptual error is the tendency of students to assume that the edges that appear longer visually always represent the length dimension, whereas in some cases, the edges actually indicate the height of the shape. This difficulty indicates that there are still misconceptions in understanding the properties of spatial shapes, especially in distinguishing the orientation and relations between geometric elements. Next, on question no. 5 with the following question: "A pyramid has a volume of 40 cm^3. If the base area is 20 cm^2, is the height always 6 cm? Explain why the base area and height can vary to get the same volume."

In question number 5, out of 30 students, a score of 49 was obtained from the maximum score of 90, so that the percentage obtained was 54% therefore the indicator of understanding the concept of classifying mathematical objects can be said to be still low. This question aims to test students' conceptual understanding of the relationship between volume, base area, and height in a pyramidal geometric shape. Through solving the problem, students are expected to be able to analyze how variations in the values of the base area and height can produce the same volume, according to the pyramid volume formula. In addition, this question also encourages students to think flexibly in solving mathematical problems and understand the dynamic nature of the elements that form the volume of a geometric shape. The following is an example of a student's answer to question number 3 which received a score of 1 on a scale of 0 to 3.

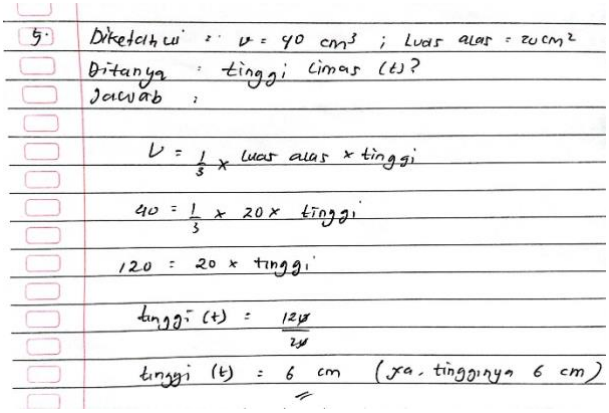

Figure 4. Student Errors in Developing Necessary and Sufficient Conditions for a Concept

Based on the students' answers above, it can be seen that students still have difficulty in explaining the relationship between the base area and height of a rectangular pyramid. This can be observed in Figure 4, where the answers given by students tend to be procedural without being accompanied by logical and conceptual reasons. Based on the results of the initial analysis that has been carried out, it was found that most students do not have a deep understanding of the basic concepts in determining the volume of a pyramid, which is indicated by their inability to connect the main variables in calculating the volume. This finding indicates that there is a need to strengthen the conceptual learning approach in order to improve students' understanding of the related material.

Conclusion and Suggestion

Based on the results of the analysis that has been done, it can be concluded that the conceptual understanding ability of students of SMP Muhammadiyah 3 Bandar Lampung in the material of flat-sided spatial figures still requires further attention. Conceptual

understanding is a fundamental aspect in learning mathematics, because it is the basis for students in constructing knowledge, connecting various concepts, and applying them in solving mathematical problems and in everyday life (Radiusman, 2020).

The results of the study showed that most students had difficulty in understanding the characteristics of polyhedral shapes, such as identifying the properties of cubes, cuboids, prisms, and pyramids, as well as in understanding the relationship between the elements that make up geometric shapes such as vertices, edges, and sides. In addition, students' understanding in applying surface area and volume formulas is still relatively low, which is indicated by errors in calculations and the inability to choose the right solution strategy.

Factors that influence students' low conceptual understanding include the lack of variation in learning strategies used by educators, this is in line with (Rimahdani et al., 2023) who emphasize the importance of using varied instructional methods and learning media to enhance students' enthusiasm for learning. They assert that teachers should implement multiple teaching strategies and media that are appropriate to the subject matter being taught, in order to make the learning process more engaging and dynamic, thereby increasing students' motivation and interest in learning, low student learning motivation, According to (Sanjaya et al., 2023), low student learning motivation may be attributed to teaching styles or methods that fail to engage students effectively. They state that diminished motivation is often influenced by the use of monotonous instructional approaches that lack variety and do not actively involve students in the learning process, and limited media and learning resources that support concrete conceptual understanding, Research by (Daryanto, 2016) indicates that the appropriate use of instructional media can enhance the efficiency of the learning process, as it enables students to engage their imagination and creativity, improve their skills and attitudes, and foster innovative and creative work. However, limitations in the use of suitable learning media may hinder students' conceptual understanding. In addition, there are still many students who only focus on memorizing formulas without understanding their meaning and application. It is stated that students tend to memorize mathematical concepts and definitions without understanding their underlying meaning, which leads to difficulties when applying these concepts to solve problems. This tendency negatively impacts their mathematical problem-solving abilities, resulting in unsatisfactory performance (Sulistiowati, 2022), so that when faced with questions with different contexts, they have difficulty solving them.

Thus, the results of this study emphasize the importance of in-depth analysis of students' conceptual understanding abilities as an initial step in improving the effectiveness of mathematics learning. More innovative and interactive learning strategies are needed, such as the use of visual media, concrete teaching aids, and problem-solving-based approaches, so that students can better understand the concept of polyhedral shapes comprehensively. By improving the quality of learning and approaches that are more in line with students' needs, it is hoped that their understanding of mathematical concepts can develop more optimally, so as to improve logical and analytical thinking skills in various situations.

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