

AN ANALYSIS OF STUDENTS' MATHEMATICAL UNDERSTANDING IN POLYHEDRAL GEOMETRY

Hafizah Syahrani Subekti¹, *Atma Murni², Yenita Roza³

¹⁻³ Universitas Riau, Indonesia

atma.murni@lecturer.unri.ac.id

ABSTRACT Mathematical understanding is a fundamental component of mathematics learning, as it underpins the development of other essential mathematical competencies. However, many students tend to rely on memorizing formulas without achieving a deep conceptual understanding. This study aimed to analyze students' mathematical understanding in the topic of three-dimensional shapes with flat surfaces at the junior high school level. A descriptive qualitative approach was employed, involving 25 students from SMP Negeri 12 Pekanbaru as research participants. Data were collected through two open-ended test items and semi-structured interviews, and analyzed using indicators of mathematical understanding, including restating concepts, applying procedures algorithmically, and connecting concepts within and beyond mathematics. The results showed that the majority of students (76%) demonstrated a low level of mathematical understanding, while 12% were classified as having moderate understanding and 12% as having high understanding. Students in the high category were able to fulfill all indicators, whereas those in the moderate and low categories experienced difficulties, particularly in applying procedures algorithmically and establishing conceptual connections. These findings indicate the need for instructional practices that emphasize conceptual understanding and support students in meaningfully connecting mathematical concepts to problem-solving contexts.

Keywords: mathematical understanding, polyhedral geometry, junior high school students, qualitative analysis, problem solving

ABSTRAK Kemampuan pemahaman matematis merupakan komponen fundamental dalam pembelajaran matematika karena menjadi dasar bagi pengembangan kemampuan matematis lainnya. Namun, dalam praktik pembelajaran, peserta didik masih cenderung mengandalkan hafalan rumus tanpa disertai pemahaman konsep yang mendalam. Penelitian ini bertujuan untuk menganalisis kemampuan pemahaman matematis peserta didik pada materi bangun ruang sisi datar di jenjang sekolah menengah pertama. Penelitian ini menggunakan pendekatan kualitatif deskriptif dengan subjek penelitian sebanyak 25 peserta didik SMP Negeri 12 Pekanbaru. Data dikumpulkan melalui dua soal uraian dan wawancara semi-terstruktur, kemudian dianalisis berdasarkan indikator kemampuan pemahaman matematis, yaitu menyatakan ulang konsep, menerapkan prosedur secara

algoritmis, serta mengaitkan konsep dalam dan luar matematika. Hasil penelitian menunjukkan bahwa sebagian besar peserta didik (76%) berada pada kategori kemampuan pemahaman matematis rendah, sementara 12% berada pada kategori sedang dan 12% pada kategori tinggi. Peserta didik dengan kemampuan tinggi mampu memenuhi seluruh indikator, sedangkan peserta didik dengan kemampuan sedang dan rendah masih mengalami kesulitan, terutama dalam menerapkan prosedur secara algoritmis dan mengaitkan konsep-konsep matematika. Temuan ini mengindikasikan perlunya penerapan strategi pembelajaran yang lebih menekankan pada pemahaman konseptual dan keterkaitan antarkonsep dalam pemecahan masalah matematika.

Kata-kata kunci: pemahaman matematis, bangun ruang sisi datar, peserta didik SMP, analisis kualitatif, pemecahan masalah

INTRODUCTION

Mathematical understanding is a fundamental ability that should be possessed by all students in mathematics learning (Adawiyah et al., 2022; Rangkuti et al., 2024). Mathematical understanding is not merely characterized by the ability to memorize definitions or formulas, but is reflected in students' ability to apply learned concepts to solve various mathematical problems (Mardiah et al., 2020; Sari & Yudhanegara, 2023; Milah et al., 2023). A strong understanding of mathematical concepts serves as an essential foundation, as it underlies the development of other mathematical abilities, such as critical thinking, mathematical communication, representation, and problem-solving skills (Nada & Erita, 2023; Pratiwi et al., 2022; Agustina et al., 2021). The interconnection among these abilities requires students not only to memorize procedures, but also to comprehend the essence of mathematical concepts from an early stage in order to support the sustainable development of their mathematical competencies. The importance of mathematical understanding is also emphasized in the objectives of secondary school mathematics curricula, which state that learning processes should encourage students to understand mathematical concepts rather than merely memorize them (Putri Khairani et al., 2021; Safari & Nurhida, 2024).

Empirical studies indicate that students' mathematical understanding remains relatively low. The study by Nada and Erita (2023) revealed that students' mathematical understanding, particularly in algebraic expressions, was still limited. Students tended to rely more on memorizing formulas than on understanding and connecting them to broader concepts when solving mathematical problems. Similar findings were reported by Yani et al. (2019), who showed that students with low and moderate ability levels continued to experience difficulties in understanding mathematical concepts, while students with higher ability demonstrated better conceptual understanding. Interviews conducted in the study further revealed that most students struggled to connect various concepts due to a lack of deep conceptual understanding and an overreliance on memorized formulas.

Differences in students' mathematical understanding have also been linked to individual learning styles. Wati et al. (2023) found that students' mathematical understanding abilities varied according to their learning styles; however, all learning style categories showed low performance on indicators related to connecting multiple concepts. Students frequently experienced difficulties in interpreting problem instructions and applying formulas appropriately, as they were accustomed to memorization without fully grasping the underlying meanings of the concepts being learned.

Low levels of mathematical understanding are further reflected in students' difficulties in comprehending concepts, determining appropriate solution strategies, linking various formulas, and applying concepts to problems that differ from those previously encountered. Yuliani et al. (2024) explained that teacher-centered learning and limited opportunities for students to construct their own understanding restrict students' meaningful engagement with mathematical concepts. In addition, teachers' dependence on textbooks and pre-prepared notes often results in less contextualized learning processes that do not sufficiently promote deep conceptual understanding (Fariyani et al., 2025).

These issues are not only evident in the literature but are also observable in classroom practice. Based on interviews conducted by the researchers with a mathematics teacher at SMP Negeri 12 Pekanbaru, students' learning achievement in the topic of polyhedral geometry was found to be relatively low. The results of daily assessments showed that the majority of students had not yet achieved the Minimum Mastery Criteria (KKM). Out of 31 students, only 8 students (approximately 25.8%) met the KKM, while the remaining 23 students (74.1%) were below the required standard. This low level of achievement is presumed to be related to students' weak conceptual understanding of polyhedral geometry, which led to difficulties in solving problems related to the topic.

This condition occurred among students categorized as Phase D learners at the junior secondary level, as defined in the structure of the Merdeka Curriculum. At this stage, students are expected to develop logical and abstract thinking abilities and to construct an integrated understanding of conceptual, procedural, and inter-conceptual connections (Weigand et al., 2025; Nuralam et al., 2024). Phase D is considered a strategic stage for examining students' mathematical understanding in greater depth. The selection of this phase in the present study aims to obtain a comprehensive picture of students' meaningful understanding of mathematical concepts, particularly in polyhedral geometry, which requires visual and spatial skills as well as the ability to connect geometric concepts holistically (Jablonski & Ludwig, 2023).

Based on the issues described above, this study aims to identify students' mathematical understanding in polyhedral geometry. The study focuses on analyzing representations of conceptual understanding, procedural understanding,

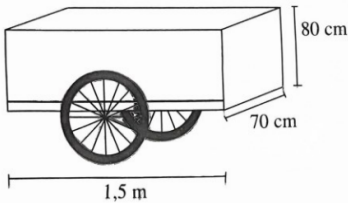
and inter-conceptual connections as reflected in students' solutions to story-based problems designed in a format similar to the Minimum Competency Assessment. The findings are expected to provide strategic insights for teachers in designing more meaningful mathematics instruction that aligns with the characteristics and learning needs of junior secondary school students.

METHODS

This study employed a descriptive qualitative research approach. The primary focus of the study was to describe students' mathematical understanding as reflected in their performance on tasks related to polyhedral geometry. The analysis of mathematical understanding was based on three indicators: (1) the ability to restate previously learned concepts, such as restating the concept of a prism; (2) the ability to select, use, and apply appropriate procedures or operations algorithmically in problem-solving situations; and (3) the ability to connect multiple concepts related to polyhedral geometry.

The study was conducted at SMP Negeri 12 Pekanbaru during the second semester of the 2024/2025 academic year. The research participants consisted of 25 eighth-grade students, who are categorized as Phase D learners according to the structure of the Merdeka Curriculum. Data were collected through written tests and interviews. The test was designed to obtain an overview of students' mathematical understanding of polyhedral geometry, while interviews were conducted individually with selected students representing high, moderate, and low levels of mathematical understanding. The interviews aimed to explore the underlying reasons for students' errors and difficulties in solving the given problems.

1. Perhatikan gambar berikut!




Pak Evan adalah seorang tukang las. Ia mendapatkan pesanan untuk membuat 6 rangka gerobak. Untuk membuat rangka tersebut, Pak Evan menggunakan besi hollow. Harga besi hollow adalah Rp15.000,00 per meter.

- Jelaskan bagian-bagian dari gerobak yang perlu dihitung untuk membuat rangka gerobak!
- Hitunglah panjang seluruh besi hollow yang dibutuhkan untuk membuat satu rangka gerobak!
- Tentukan total biaya yang harus dikeluarkan pak evan untuk membuat semua rangka gerobak tersebut!

Figure 1. Mathematical Understanding Test Item 1 on Polyhedral Geometry
The test instrument consisted of two open-ended questions that were developed to align with the indicators of mathematical understanding. Prior to administration, the test items were validated by mathematics education experts to ensure clarity of

language, content validity, and alignment with the intended indicators. The characteristics of the items were designed to be comparable to those used in the Minimum Competency Assessment.

2. Perhatikan gambar berikut!



Setelah bencana banjir melanda Kecamatan Rumbai, para relawan mendirikan tenda darurat untuk menampung para pengungsi. Setiap tenda memiliki volume $90 m^3$ dan tinggi 3 meter, serta digunakan untuk menampung 10 orang.

- Jelaskan bentuk geometri dari tenda tersebut dan unsur-unsurnya!
- Hitunglah luas alas tenda tersebut!
- Hitunglah luas ruang yang tersedia untuk masing-masing orang dalam tenda tersebut!

Figure 2. Mathematical Understanding Test Item 2 on Polyhedral Geometry

The two test items used to assess students' mathematical understanding are presented in Figures 1 and 2. These items functioned as measures of mathematical understanding based on the three established indicators. In part (a), students were required to restate the relevant polyhedral geometry concepts presented in the problem. In part (b), students were asked to determine and apply appropriate procedures or operations to solve the problem. In part (c), students were required to connect polyhedral geometry concepts to the contextual situation provided.

Data analysis was conducted in a systematic and iterative manner through three main procedures. First, data reduction was carried out by selecting, examining, and simplifying raw data derived from students' written responses and interview transcripts. This stage aimed to identify students' patterns of thinking and problem-solving strategies. Second, during the data display stage, the reduced data were organized and presented in the form of descriptive narratives, tables, and other relevant visual representations to facilitate the identification of emerging patterns. Third, conclusions were drawn through an in-depth examination of the analyzed data. The conclusions were formulated based on consistent trends in the findings and were closely aligned with the research focus, ensuring that the interpretations were objective and scientifically accountable.

FINDING AND DISCUSSION

The results of the analysis of students' responses to the two open-ended test items, which cover indicators of mathematical understanding, are presented in Table 1.

Table 1. Results of the Mathematical Understanding Test

Statistical Measure	Mathematical Understanding Results
Number of data	25
Mean	41.33
Maximum score	91.67
Minimum score	8.33
Standard deviation	24.05
Variance	578.58
Median	37.50
Mode	33.33

Source: Processed Research Data

Table 1 shows variations in students' mathematical understanding. The average test score indicates that students' mathematical understanding is generally in the low category. The relatively large gap between the maximum and minimum scores reflects a significant disparity in students' levels of mathematical understanding.

Based on the data presented in Table 1, students' mathematical understanding levels were categorized using the ideal mean and ideal standard deviation. The results of this categorization for the 25 students are presented in Table 2.

Table 2. Classification of Students' Mathematical Understanding Levels

Score Range	Number of Students	Percentage	Category
$N \geq 90$	3	12%	High
$46 \leq N < 90$	3	12%	Moderate
$N \leq 46$	19	76%	Low

Note: N = students' test scores

Source: Processed Research Data

Table 2 indicates that the majority of students are still at a low level of mathematical understanding and therefore require further instructional support to reach moderate or high levels. Only a small proportion of students demonstrate higher levels of understanding. This condition highlights the need to improve the quality of mathematics instruction, either through the implementation of more appropriate learning strategies or targeted interventions, so that students' mathematical understanding can develop optimally.

Further analysis was conducted based on the achievement of each indicator of mathematical understanding for each test item. The results of this analysis are presented in Tables 3 and 4.

Table 3. Percentage of Students Answering Correctly on Test Item 1

Indicator	Percentage of Students with Correct Answers
Restating previously learned concepts	40%
Using, applying, and selecting appropriate procedures or operations algorithmically in problem solving	16%
Connecting various concepts within mathematics and beyond mathematics	20%

Table 3 shows that the largest proportion of students was able to restate previously learned concepts compared to the other two indicators. However, the percentages of students who were able to apply procedures algorithmically and connect multiple concepts remain low. This finding suggests that students' mathematical understanding tends to be limited to basic conceptual knowledge and has not yet fully developed in terms of application and conceptual connections, either within mathematical contexts or across contexts. This condition indicates the need to strengthen problem-solving skills and conceptual connections in the learning process.

Table 4. Percentage of Students Answering Correctly on Test Item 2

Indicator	Percentage of Students with Correct Answers
Restating previously learned concepts	0%
Using, applying, and selecting appropriate procedures or operations algorithmically in problem solving	16%
Connecting various concepts within mathematics and beyond mathematics	16%

Table 4 indicates that students experienced substantial difficulty in restating previously learned concepts. Their ability to implement procedures and connect concepts was also very limited. Based on the classification of students' mathematical understanding levels presented in Table 2, a further in-depth analysis was conducted for each category—high, moderate, and low. One student from each category was selected as a representative participant, and their understanding of mathematical concepts was analyzed in greater detail. This analysis was conducted using a word problem related to polyhedral geometry, specifically Test Item 1 from the developed instrument.

Students with High Mathematical Understanding Ability

Table 2 shows that 3 students (12%) are classified as having a high level of mathematical understanding. An analysis of one representative student's response from this category is presented in Figure 3.

1. Diketahui = tinggi = 80 cm / 0,8 m (4) Harga = 15.000 / meter
 Lebar = 70 cm / 0,7 m (4)
 panjang = 150 cm / 1,5 m (4)
 Ditanya : a. bagian-bagian dari gerobak yang perlu dihitung untuk membuat rangka gerobak !
 b. hitunglah panjang seluruh besi hollow yang dibutuhkan untuk membuat satu rangka gerobak !
 c. Tentukan total biaya yang harus dikeluarkan pak exan untuk membuat semua kerangka gerobak tersebut !

Jawab : a. panjang, lebar, dan tinggi. ✓ 4
 panjang = 4 buah, lebar = 4 buah, tinggi = 4 buah.
 b. $t = 0,8 \times 4 = 3,2 \text{ m}$
 $l = 0,7 \times 4 = 2,8 \text{ m}$
 $p = 1,5 \times 4 = 6 \text{ m}$
 $K = A + B + C$
 $= 3,2 + 2,8 + 6$ ✓ 4
 $= 12 \text{ m}$
 c. 12×15
 $= 72$
 $= 72 \times 15.000$ ✓ 4
 $= 1.080.000$

Jadi, total biaya yang harus dikeluarkan pak exan untuk membuat semua rangka gerobak tersebut adalah 1.080.000 Rupiah.

Figure 3. Response of a Student with High Mathematical Understanding Ability

With regard to the indicator of restating previously learned concepts, all students in this group were able to accurately restate the relevant concepts based on the given object. This was evident when they explained the parts of the cart frame that needed to be calculated. In doing so, students recalled and restated concepts that had been previously learned, such as length, width, height, perimeter, and the structural components of the frame. This ability indicates that students were able to clearly and appropriately restate mathematical concepts according to their understanding.

For the indicator related to selecting and applying procedures algorithmically in problem solving, all students in this group were able to choose correct and appropriate procedures or operations. This was observed when they calculated the total length of hollow steel required for one cart frame. At this stage, students needed to determine suitable calculation steps, such as computing perimeters, identifying the number of sides, or determining the total length of the frame, and

then applying the appropriate arithmetic operations. This reflects their ability to organize problem-solving procedures systematically in an algorithmic manner.

Regarding the indicator of connecting various concepts within mathematics and beyond mathematics, students in this group demonstrated accurate and relevant connections. They were able to determine the total cost that Mr. Evan needed to pay. In this process, students calculated the length of the steel using mathematical concepts and then connected these results to unit price information, which originates from a non-mathematical context. This ability indicates that students were capable of integrating cross-disciplinary concepts to solve contextual problems.

The interview results further revealed that students with high mathematical understanding were able to comprehend concepts quickly, select appropriate solution strategies, and connect various mathematical ideas fluently. One student stated, "I first calculated the length of each part of the cart, then added them all together, and finally multiplied the total by the price per meter." These students also appeared confident when explaining their answers and were able to relate the mathematical material to real-life situations.

Students with Moderate Mathematical Understanding Ability

Table 2 indicates that students classified as having a moderate level of mathematical understanding account for 12% of the participants. An analysis of one representative student’s response from this category is presented in Figure 4.

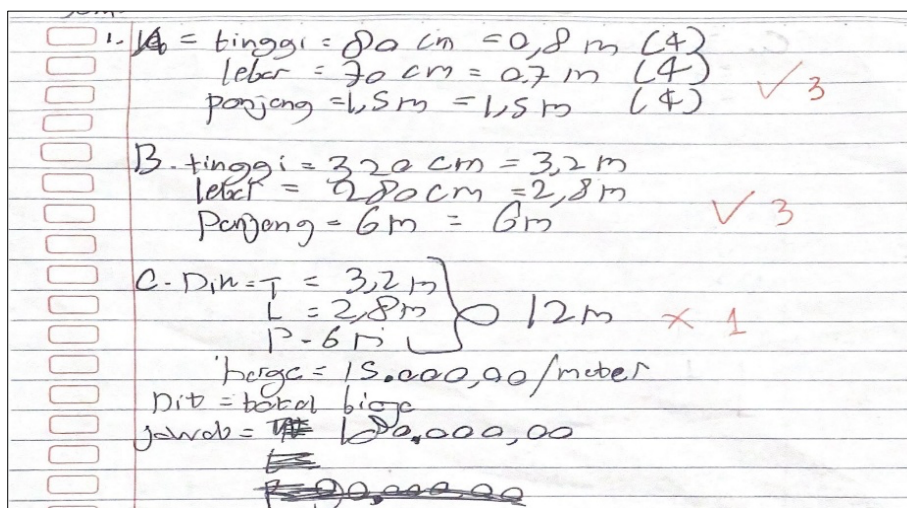


Figure 4. Response of a Student with Moderate Mathematical Understanding Ability

With respect to the indicator of restating previously learned concepts, the student demonstrated a reasonably good understanding of measurement concepts but showed incomplete understanding of the structure of a rectangular prism and its edges. This was evident when the student correctly wrote the dimensions (length,

width, and height) and converted them into meters. However, although important numerical values were identified, the student did not clearly describe the structural components of the frame, such as specifying four length edges, four width edges, and four height edges.

Regarding the indicator of selecting and applying procedures algorithmically in problem solving, the student's procedure was incomplete and did not follow the appropriate algorithm, resulting in an inaccurate final answer. As shown in Figure 4, the student directly summed the main dimensions (length, width, and height) to obtain a total of 12 meters, without calculating the total length of all edges using the correct formula ($4 \times \text{length} + 4 \times \text{width} + 4 \times \text{height}$).

For the indicator of connecting concepts within mathematics and beyond mathematics, the student attempted to relate mathematical concepts such as length, price, and cost; however, the application was not accurate. Based on Figure 4, the student multiplied the obtained length (12 m) by the unit price of IDR 15,000 per meter to calculate the cost, but the final result of IDR 60,000 was incorrect. The calculation should have accounted for six carts rather than only one, leading to an inaccurate application of the cost concept.

The interview results revealed that students with moderate mathematical understanding possessed a fairly good grasp of the dimensions of a rectangular prism and unit conversion. One student stated, *"I first converted everything into meters so that the units were the same."* However, the student experienced difficulties in identifying and accounting for the edges in detail. The student tended to simplify the calculation procedure by directly summing the dimensions without applying the appropriate formula. As the student explained, *"I thought I could just add the length, width, and height, and then multiply the result by the price of the steel."* Furthermore, the student calculated the cost for only one cart instead of six, which led to an inaccurate application of the cost concept. When asked about this, the student responded, *"I didn't realize it should be six; I thought it was just one."*

Students with Low Mathematical Understanding Ability

Table 2 shows that the majority of students, accounting for 78%, are classified as having a low level of mathematical understanding. An analysis of one representative student's response from this category is presented in Figure 5.

Regarding the indicator of restating previously learned concepts, students in this group were not able to express the concepts completely. They were only able to mention general measurements without understanding the meaning of the frame as a structure composed of lines or edges. As shown in Figure 5, the student merely wrote "length, width, height of the cart edges" without providing a detailed explanation of the frame structure.

For the indicator related to selecting and applying procedures algorithmically in problem solving, students were unable to identify and apply appropriate procedures to solve the given problem. As illustrated in Figure 5, the student selected an incorrect solution procedure by directly using multiplication without first calculating the total length of all edges using the appropriate formula ($4l + 4w + 4h$).

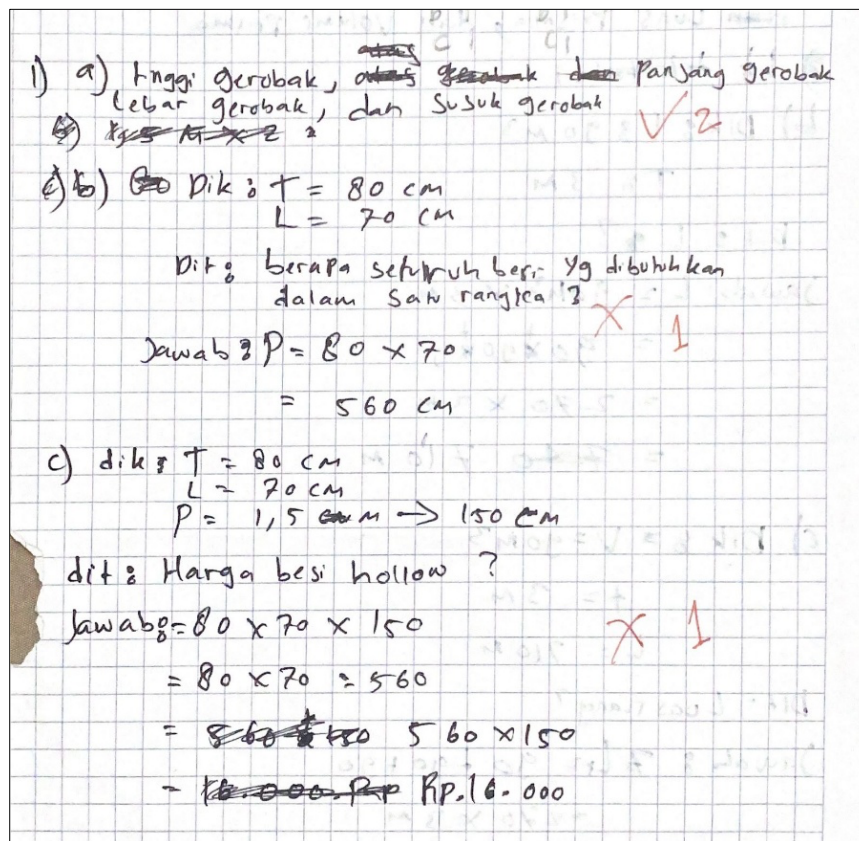


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In terms of connecting concepts within mathematics and beyond mathematics, students were unable to relate several essential concepts that should have been interconnected. Figure 5 shows that the student failed to connect the concept of

length with unit conversion (from centimeters to meters). The student also did not understand the relationship between length calculation and cost determination based on the price per meter. The student stopped at an incorrect numerical result without linking the mathematical steps to the real-life context of purchasing hollow steel.

Based on interview results and students' written responses, it was found that students in this group experienced difficulties in restating concepts comprehensively, as they were only able to mention general dimensions (length, width, and height) without understanding the detailed structure of the frame, such as the number of edges. One student stated, *"I saw that the question asked about the parts of the cart, so I thought I only needed to mention the parts without calculating their measurements."* Students were also unable to select appropriate calculation procedures, as they tended to multiply numbers without realizing that the task required summing the lengths of all edges. Furthermore, students were unable to connect various concepts, such as converting units from centimeters to meters or relating length calculations to cost estimation. These findings indicate that students in the low category have not yet developed a coherent and sustained conceptual understanding. As expressed by one student, *"I thought it was enough to multiply the length by the width to get the result and then use it to calculate the cost."* Another student stated, *"I didn't know I had to convert it to meters. I just used the numbers as they were."* This condition suggests that students require more contextual learning approaches that emphasize the gradual construction of meaning.

Based on the analysis of the mathematical understanding test, it can be concluded that for the indicator of restating previously learned concepts, students with high and moderate levels of understanding were able to perform well, whereas students with low understanding were not. For the indicator of selecting, using, and applying procedures algorithmically in problem solving, students with high understanding demonstrated strong performance, while those with moderate and low understanding experienced noticeable difficulties. Similarly, for the indicator of connecting concepts within mathematics and beyond mathematics, students with high understanding were able to make appropriate connections, whereas students with moderate and low understanding showed limited ability to do so.

The findings of this study are consistent with those of Syaifar et al. (2022), who reported that students with high ability were able to select and apply procedures step by step, and Meidianti et al. (2022), who found that high-ability students could connect concepts across topics and with everyday life. These findings underscore the importance of instructional strategies that support the development of mathematical understanding at all levels. In line with Prayulia Trisandi and Saragih (2024), students with low mathematical understanding tend to experience difficulties in understanding concepts, selecting appropriate procedures, connecting

various formulas, and applying concepts to problems that differ from previously learned examples.

CONCLUSIONS AND RECOMMENDATIONS

The findings indicate that the majority of students demonstrate a low level of mathematical understanding. Students classified as having high mathematical understanding were able to fulfill all three indicators: (1) restating previously learned concepts, (2) selecting, using, and applying procedures or operations algorithmically in problem solving, and (3) connecting concepts within mathematics as well as across non-mathematical contexts. In contrast, students in the moderate and low categories had not yet mastered the latter two indicators, particularly the ability to apply procedures algorithmically and to establish connections among concepts.

This study was limited to three levels of mathematical understanding (high, moderate, and low). Therefore, future research is recommended to involve students from more diverse school contexts and ability levels in order to obtain a more comprehensive understanding of students' mathematical understanding. Teachers are encouraged to implement contextual learning models, such as Discovery Learning and Problem-Based Learning, to support students in constructing deeper conceptual understanding and in connecting mathematical concepts to real-life situations. This recommendation is grounded in the study's findings, which show that many students continue to experience difficulties in accurately restating previously learned concepts. These difficulties highlight the need for instructional approaches that position students as active agents in the construction of knowledge, so that mathematical concepts are not merely memorized but meaningfully understood within relevant contexts.

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