

Analysis of Students' Conceptual Understanding of Pythagorean Prerequisite Concepts

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Abstract

This study aims to determine students' ability to understand the prerequisite material for Pythagorean concepts. The study was conducted using a descriptive qualitative approach. The subjects of this study were students of class VIII B at SMP Adhyaksa 1 in Jambi City. Data collection involved written tests, interviews, and documentation, followed by analysis through data reduction, data presentation, and the formulation of conclusions. Data analysis was conducted based on concept comprehension indicators, namely 1) restating a concept, 2) writing down concepts in various mathematical representations, 3) using certain procedures, and 4) applying a concept. Based on the findings, of the 14 students, 7 were classified as having low comprehension, 5 were categorized at a moderate level, and 2 students achieved a high level of comprehension. This shows that students' conceptual understanding abilities vary. The results of the study show that students' conceptual understanding of the prerequisite material on Pythagoras tends to be low, with 50% in the low category. Some students showed fairly good achievement in the indicators of restating concepts and representing concepts. However, students were still weak in the indicators of selecting and using specific procedures and applying concepts.

Keywords: Conceptual Understanding Ability, Prerequisite Material, Pythagorean

Introduction

Conceptual understanding is a skill that students need in the mathematics learning process (Radiusman, 2020). Understanding is viewed as a process by which a person acquires knowledge (Sufianto, 2019). Conceptual understanding constitutes an aspect of mathematical competence, which encompasses the capacity to comprehend mathematical concepts in depth, establish connections between ideas, and apply these concepts in real-world contexts (Kilpatrick et al., 2001). An individual's comprehension of a particular concept is evidenced by the ability to establish a connection between newly acquired knowledge and existing knowledge (Ausubel, 1968). It's important to understand a concept because it helps students see the difference between different ideas and do meaningful calculations in different situations. Students can express mathematical ideas in their own words and understand them. They can sort math objects into different categories. They can apply math ideas using step-by-step processes, explain ideas, and connect different ideas (Apriyanti et al., 2023).

According to Cahani et al. (2021), there are several indicators of conceptual understanding, namely explaining a concept, using a concept in different situations, and

developing several consequences of a concept. Then, the indicators of conceptual understanding that the researcher used in this study according to BNSP (2006) are: 1) restating a concept, 2) writing concepts in various mathematical representations, 3) being able to use and select certain procedures, and 4) applying concepts.

In line with Bariyah et al. (2024), mastering new concepts cannot be done independently but must be built upon previous concepts that students have learned. Students with good mastery of prerequisite material usually find it easier to understand new concepts. Specifically, for the Pythagorean theorem material at the junior high school level, students must first understand prerequisite material such as right triangles, quadratic functions, units of length and distance, and the concept of squares to support students in understanding the Pythagorean theorem in depth. The material serving as a prerequisite for the concept ability test questions encompasses the characteristics of right triangles, encompassing their type, shape, and angles. Additionally, there is material on square flat shapes. In this material, the researcher wants to assess students' ability in quadratic numbers. The researcher will do this by calculating the area of a square and then measuring students' ability to represent it. Then there is the material on measurement units. The researcher uses this material as a prerequisite because measuring students' representation ability is not only about image representation but also other mathematical representations.

The Pythagorean theorem is a theorem or proposition that states that in a right triangle, the square of the side opposite the right angle is equal to the sum of the squares of the sides forming the right angle (Khoerunnisa et al., 2021). The Pythagorean theorem is important to master because it is closely related to solving geometry and other mathematical problems.

In reality, many students in Indonesia still have low conceptual understanding skills (Hermanto et al., 2021). Based on the results of a survey conducted by the Programme for International Students Assessment (PISA) in 2022, Indonesia ranked 69th out of 85 participating countries and scored 366 in the mathematics category (OECD, 2023). This means that students have a hard time understanding and applying math ideas in different situations. Students' lack of mastery of prerequisite material is one of the causes of their mistakes in solving problems (Astuti et al., 2023). As posited by Hikmi et al. (2024), a contributing factor to students' challenges in addressing problems concerning the Pythagorean theorem is their inadequate grasp of prerequisite concepts.

A study of interviews conducted with mathematics teachers at SMP Adhyaksa 1 in Jambi City indicates that there is considerable variance in students' conceptual understanding in class. This condition poses a challenge in teaching the Pythagorean theorem and highlights the need for initial mapping of students' conceptual understanding based on prerequisite material.

This study is a preliminary observational study to determine students' comprehension of the prerequisite material for the Pythagorean theorem before conducting classroom learning. With this study, the researcher hopes that it can provide teachers with an overview of students' initial abilities before teaching the Pythagorean theorem so that teachers can adjust their teaching to the students' abilities.

Method

The present study was conducted using a descriptive qualitative approach. A qualitative approach enables researchers to explore students' understanding during the learning process in greater depth (Miles et al., 2014). The present study was conducted through a descriptive analysis of the students' concept comprehension test results on the prerequisite material of Pythagoras, in addition to conducting interviews with students to assess their answers to the questions posed. The research was supplemented with documentary data. In the course of analyzing the research data, the researcher reduced the data by selecting interview data and tests relevant to the research objectives. Then, the researcher presented the sorted data in tabular form and transcribed the interviews. Subsequently, the researcher arrived at conclusions and verified the data. The validity of the data in this study was maintained through the application of technique triangulation and source triangulation. According to Sugiyono (2015), technique triangulation is an effort to obtain data from one source using more than one data collection technique.

The research was conducted on eighth-grade students at SMP Adhyaksa 1 in Jambi City around August-September 2025. The subjects in this study were 14 students in class VIII B, selected using purposive sampling.

Data collection was carried out by administering tests and conducting interviews. To assess the students' conceptual understanding, a test consisting of four essay questions on the prerequisite material of Pythagoras was administered based on conceptual understanding indicators. The researcher then conducted interviews with teachers and students to reinforce

the data obtained. In this study, the researcher only used four indicators according to (BNSP, 2006), namely:

1. Restating a concept
2. Writing concepts in various mathematical representations
3. Using and selecting specific procedures
4. Applying concepts

The researchers employed a reduced set of four indicators of concept understanding, focusing their analysis on those that could represent the main aspects of concept understanding and could be empirically observed through student responses.

The following is the scoring of students' conceptual understanding abilities according to the indicators used, modified from (Alzanatul Umam & Zulkarnaen, 2022).

Table 1. Scoring of concept understanding ability indicators

No	Indicator	Description	Score
1.	Restating a concept	Does not provide an answer	0
		Answering, but without explanation	1
		Answering using a method but not yet correctly	2
		Answered, but not entirely correct	3
		The answer is understandable and correct.	4
2.	Writing concepts in various representations	Did not provide an answer	0
		Answering, but without explanation	1
		Answering using a method but not yet correctly	2
		Answered, but not entirely correct	3
		Answered correctly, explanation is understandable and correct	4
3	Using and selecting specific procedures	Did not provide an answer	0
		Answering, but without explanation	1
		Answering using a method but not yet correctly	2
		Answered, but not entirely correct	3
		The answer is understandable and correct.	4
4.	Applying concept	Does not provide an answer	0
		Answering, but without explanation	1
		Answering using a method but not yet correctly	2
		Answered, but not entirely correct	3
		Answered correctly, explanation is understandable and correct	4

The score data obtained based on the table will be used in the calculation with the following formula $N = \frac{\text{Total score}}{\text{maximum score}} \times 100\%$ The score categories used in this study are the scoring criteria according (Rihi & Sajja, 2022), with details as follows: a percentage of $N > 70\%$ falls into the High category, a percentage of $55\% \leq N \leq 70\%$ falls into the Moderate category, and $N < 55\%$ falls into the Low category.

Results and Discussion

This study aims to descriptively analyze students' conceptual understanding of the prerequisite material on Pythagoras based on conceptual understanding indicators. The results of the analysis show that students' conceptual understanding varies. Based on the results of grouping students' conceptual understanding abilities, they were categorized as high, moderate, and low. In general, students' conceptual understanding abilities in the prerequisite material of Pythagoras tended to be in the low category. This statement was obtained from the results of the analysis of students' conceptual understanding ability tests presented in Table 2 below:

Table 2. Analysis of Students' Conceptual Understanding Ability

No	Category	Code name	Number	Percentage
1	High	KY,TR	2	14%
2	Moderate	HN,CL,AR,NA,RH,	5	36%
3	Low	DZ,AM,FW,DV,NJ,RG,KZ	7	50%

From the analysis based on the table above, it can be seen that 2 students obtained a high category with a percentage of 14%. Five students obtained a low category with a percentage of 36%. And 7 students obtained a low category with a percentage of 50%. The results of the analysis in the table show the students' ability to restate a concept, represent a concept, choose a specific procedure, and apply the concept obtained from calculations based on the scoring of concept understanding indicators. Table 3 below presents the percentage of student scores based on each question item.

Table 3. Percentage of Student Scores Based on Test Items

	Percentage of Student Scores				Percentage Overall
	Question 1	Question 2	Question 3	Question 4	
Percentage	60%	66%	58%	38%	55%
Category	Moderate	Moderate	Moderate	Low	Moderate

The findings of the research, as presented in Table 3, indicate that the students' comprehension of right-angled triangles in question number 1 is represented by an average percentage of 60%. The students' conceptual understanding related to the area of a square in question number 2 was 66%, and question number 4 had a percentage of 38%. The mean percentage of correct responses from students in question 3, which pertained to units of measurement, was 58%. The subsequent section delineates the students' aptitude for grasping the Pythagorean theorem prerequisite material, as measured by four distinct concept understanding indicators.

Concept Understanding Ability

The researcher's analysis of the data shows that students' concept comprehension abilities vary from high to low. This can be seen based on the concept comprehension indicators, namely restating a concept, writing down a concept in various mathematical representations, using and selecting specific procedures, and applying concepts. Each indicator has a scoring scale from 0 to 4 according to the scoring in Table 1. With the scoring according to Table 1 and the categorization in Table 2, it was found that out of a total of 14 students, 2 students (14%) obtained the high category. Then, 5 students (36%) obtained the moderate category, and 7 students (50%) obtained the low category.

Question number 1

The capacity to comprehend the notion of the Pythagorean theorem, as evidenced by the analysis of right-angled triangles presented in Table 3, was assessed to yield a Moderate percentage of 60%. The indicators of conceptual understanding contained in this question were the indicators of restating a concept and writing down the concept in various representations. An exemplar of a student's response is presented in Figure 1.

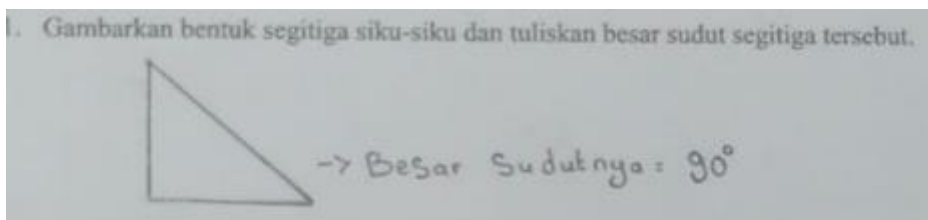


Figure 1. Example of the answer to question number 1

An analysis of the students' responses indicates their ability to describe the geometry of a right triangle and calculate angle measurements. However, subsequent in-depth interviews revealed that the students lacked certainty regarding the precise angle of a right triangle that measures 90 degrees. The following are the results of interviews with students.

Researcher: "Is it true that what you drew was a right triangle?"

Student: "Yes."

Researcher: "Why?"

Student: "Because there is a perpendicular side".

Researcher: "Explain how you know the angle of a right triangle is 90 degrees."

Student: "We learned that a right triangle has an angle of 90 degrees."

Researcher: "Do you know which angle is meant?"

Student: "This one (pointing to the perpendicular angle with a little hesitation)."

However, the students recalled the definition of a right triangle, which stipulates that it possesses a 90-degree angle. This suggests that the students may have lacked a comprehensive grasp of the concept of a right triangle. As demonstrated in Figure 1, the students demonstrated a sufficient level of comprehension of the concept, as evidenced by their ability to formulate it in diverse representations and restate it accurately. However, the level of proficiency in these activities was not considered to be optimal.

Question number 2

According to the results indicated in Table 4, 66% of the respondents demonstrated an understanding of the prerequisite material concerning the Pythagorean concept of box units in squares. This understanding was classified under the Moderate category. This suggests that the majority of students possess the capacity to conceptualize boxes as a unit of area. However, as illustrated by the responses of students depicted in Figure 2, a proportion of students continue to grapple with this fundamental concept.

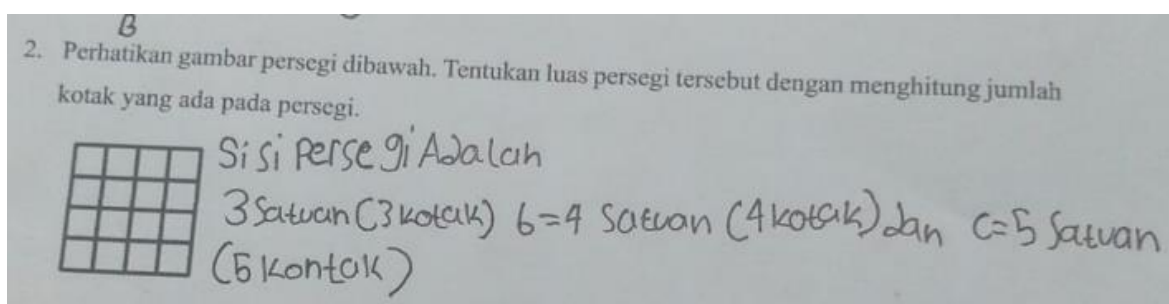


Figure 2. Example of student answers for question number 2

The concept comprehension indicators contained in question number 2 are as follows: restating a concept using certain procedures, and writing down concepts in various representations. A thorough examination of the percentage results presented in Table 4 reveals that students have not yet demonstrated full compliance with the established indicators. It is evident that a multitude of factors contribute to students' challenges in responding to inquiries. A salient factor is their comprehension of fundamental concepts, which is often deficient.

The results of the interviews conducted by researchers with teachers indicate that students encounter challenges when performing multiplication operations.

"Students still have a hard time with multiplication and division, especially with large numbers." said the math teacher at SMP Adhyaksa 1 in Jambi City.

Additionally, the researchers' observations and interviews revealed that students had difficulty mastering multiplication, especially with large numbers. This deficiency may hinder students' ability to solve problems effectively, as they may lack a firm grasp of fundamental concepts. This finding aligns with the conclusions of Mahtuum et al. (2020) that mathematics learning is inherently interconnected. It is crucial for students to develop a solid understanding of fundamental concepts before tackling more complex problems.

Question number 3

The comprehension of the prerequisite material concerning Pythagorean units of length measurement demonstrated a completion rate of 58%. This finding suggests that a significant proportion of the student population possesses a fundamental understanding of measurement units and has demonstrated proficiency in the concept comprehension indicators related to writing concepts in various forms and the ability to employ specific procedures. However, their achievement is not yet optimal, as illustrated by one of the students' answers in Figure 3 below:

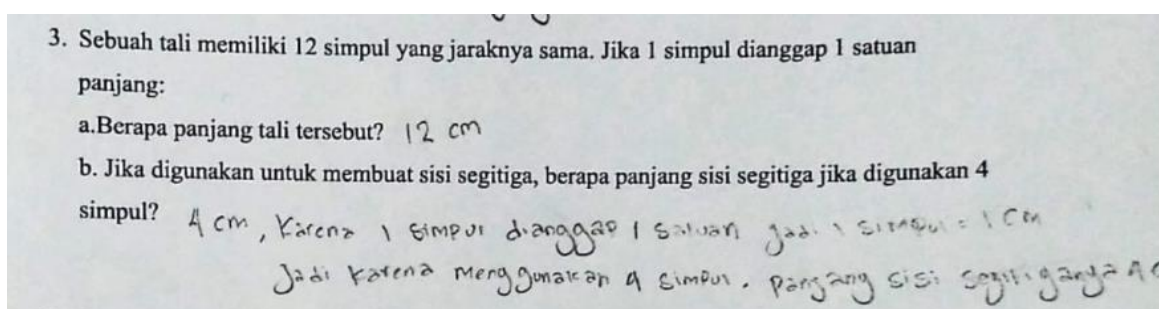


Figure 3. Example of the correct answer from student number 3

As illustrated in Figure 3, it is evident that students have comprehended the unit of measurement. The question posits that 1 knot is equivalent to 1 unit, and students are expected to provide a thorough explanation of their reasoning. A proportion of the student body demonstrated an inability to complete the question correctly. The following responses from students exemplify this phenomenon.

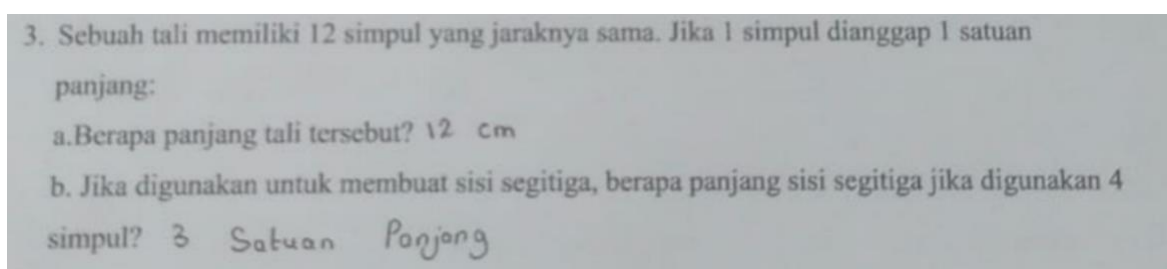
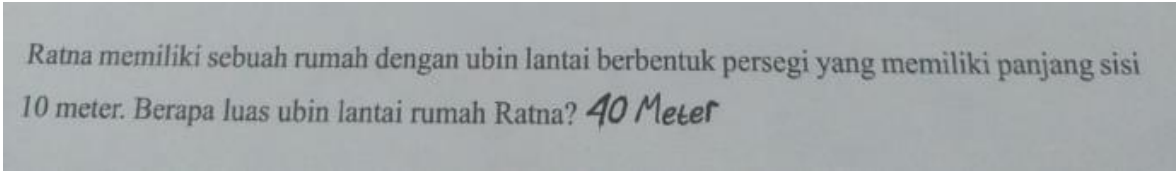


Figure 4. Example of incorrect answer from student number 3

As illustrated in Picture 4(a), the students have determined that one knot is equivalent to one unit of length. Consequently, they perceive the length of the rope to be 12 units. Regarding the students' responses in centimeters, it was observed that they experienced perplexity regarding the concept of the unit of length. Consequently, they chose to document their responses in centimeters. In part B, the students correctly identified the unit but miscalculated the length of the triangle's sides. This is due to their uncertainty about the appropriate method for representing it as a triangle. As (Sari et al., 2021) indicated, students' inadequate representational competence is due to their limited ability to translate representations. This assertion is further substantiated by (Sepriliani et al., 2022) who contend that a salient factor contributing to students' inability to effectively represent is their tendency to focus on a single question, thereby neglecting to attend to other questions.

Question number 4

The comprehension of the Pythagorean theorem, specifically its application to the calculation of the area of a square, demonstrated a completion rate of 38%. This percentage is considered low. This finding suggests a gap in students' understanding of the methods for solving contextual problems concerning the area of a square. The following illustration depicts the responses given by the students in Figure 5 below.



Ratna memiliki sebuah rumah dengan ubin lantai berbentuk persegi yang memiliki panjang sisi 10 meter. Berapa luas ubin lantai rumah Ratna? *40 Meter*

Figure 5. Example of a student's incorrect answer to question number 4

As demonstrated in the provided illustration, the student provided an incorrect response when confronted with a contextual problem concerning the calculation of the area of a square. The student's inability to solve the problem was attributable to various factors. One such challenge pertained to the student's inability to solve the problem due to their lack of mastery over the preceding related material. The subsequent example illustrates the appropriate response from student number 4.

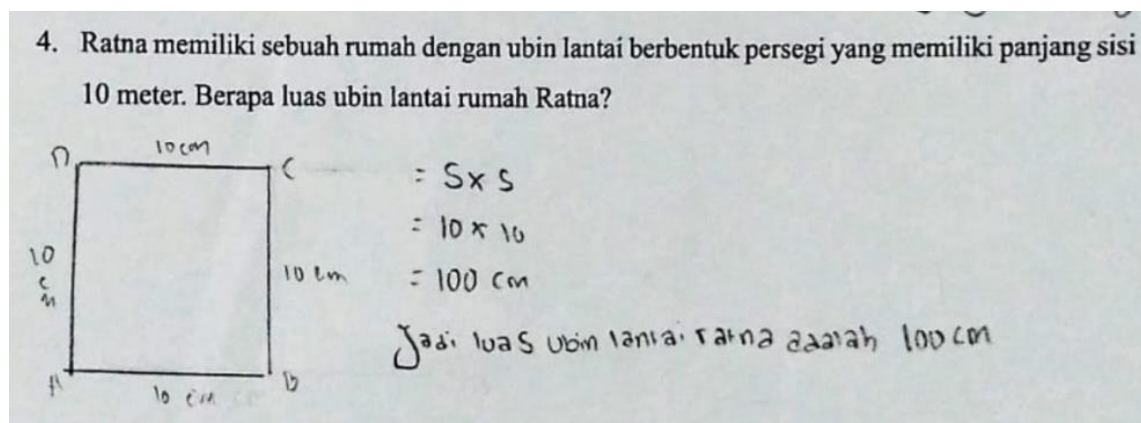


Figure 6. Example of the correct answer from student number 4.

In Figure 6, the student's answer is in the high category. This answer is very different from the answer in Figure 5. In this example, the solution is explained in detail, with each step clearly following the procedure. The ideas used are right, and the math is correct.

Question 4 has several parts that will demonstrate your understanding of the concept. These parts include correctly using the idea, carrying out the steps in the correct order, and explaining the idea in your own words. Based on the data in Table 4, students have not fully met these criteria. Students in the low category did not achieve the indicators for applying the concept. Students in the high and medium categories have achieved the indicators for using specific procedures. Some students in the low category have also achieved these indicators when applying the concept. In line with Setiawan (2024) research, students' ability to apply concepts is low, with 27 students, or 87%, performing poorly.

This shows that most students have difficulty integrating conceptual understanding with problem-solving procedures. Students can follow the steps of a solution mechanically but do not understand why these steps are used. This is evident in the inability of students, particularly those in the low category, to articulate the concepts or ideas in their own words. These findings suggest that students' conceptual understanding is procedural and has not developed conceptually.

Conclusion and Suggestion

Based on the results of the study of the conceptual understanding of eighth-grade students at SMP Adhyaksa 1 in Jambi City on the prerequisite material of Pythagoras, the researcher concluded that the overall concept understanding of students was classified as low, with a percentage of 50% for 7 students. Then, when viewed from the prerequisite material indicators on the Pythagorean theorem concept, the conceptual understanding

ability of eighth-grade students at Adhyaksa 1 Junior High School in Jambi City was classified as moderate. This was based on the results of the students' answers, which, out of a total of four questions, three questions were classified as moderate and one question was classified as low. Students had difficulty understanding the meaning of the questions, especially story-type questions. One of the factors that influenced the students' difficulty in completing the questions was their lack of understanding of the prerequisite concepts or related concepts. This study has several limitations. First, the research subjects were limited to one class of 14 students, so the results cannot be generalized. Second, the study was micro in nature. Additionally, the prerequisite material analyzed focused on right triangles, squares, and units of measurement. Therefore, other prerequisites that could affect understanding of the Pythagorean Theorem were not examined in depth. As this study is preliminary, further research is needed to address student issues. Therefore, the researchers hope that future studies will support students' conceptual understanding.

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