

Exploration of Vocational Students' Mathematical Understanding: A Case Study on Trigonometric Ratios

Irmawati Liliana Kusuma Dewi^{1*}, Cita Dwi Rosita², Muchamad Subali Noto³,
Farhan Ferdiansyah⁴

Mathematics Education, Universitas Swadaya Gunung Jati
Pemuda Raya Street, Cirebon, West Java, Indonesia

^{1*}irmawati.liliana@gmail.com; ²citadwirosita@gmail.com; ³msnoto@ugj.ac.id;

⁴farhanferdiansyah0604@gmail.com

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Abstrak

Penelitian bertujuan mengeksplorasi kemampuan pemahaman matematis siswa Sekolah Menengah Kejuruan (SMK) pada materi perbandingan trigonometri. Penelitian menggunakan pendekatan kualitatif dengan metode studi kasus. Subjek penelitian yaitu tiga siswa SMK yang mewakili kategori kemampuan tinggi, sedang, dan rendah, dipilih secara purposive. Data dikumpulkan melalui tes dan wawancara semi-terstruktur. Hasil penelitian menunjukkan adanya profil pemahaman matematis yang berbeda pada setiap kategori kemampuan. Siswa berkemampuan tinggi mampu mengidentifikasi konsep trigonometri, menggunakan berbagai representasi, serta mengaitkan perbandingan trigonometri dengan bentuk simbolik dan kontekstual, meskipun masih ditemukan kelemahan pada penguasaan materi prasyarat aljabar. Siswa berkemampuan sedang umumnya mampu menyelesaikan soal rutin dan representasional, namun mengalami kebingungan konseptual dalam menentukan sudut acuan dan menafsirkan perbandingan trigonometri pada situasi non-rutin. Adapun siswa berkemampuan rendah menunjukkan pemahaman yang terfragmentasi, ditandai dengan kesulitan mengidentifikasi konsep yang relevan, menghubungkan informasi soal cerita dengan representasi segitiga siku-siku, serta menjelaskan alasan penyelesaian. Temuan ini mengindikasikan bahwa kesulitan siswa pada materi trigonometri tidak semata-mata bersifat prosedural, tetapi berkaitan erat dengan lemahnya pemahaman konseptual dan penguasaan materi prasyarat.

Kata Kunci: Pemahaman Matematis; Siswa SMK; Studi Kasus Kualitatif; Trigonometri.

Abstract

This study aims to explore vocational high school students' mathematical understanding of trigonometric ratios. A qualitative case study approach was employed. The participants were three vocational students representing high, medium, and low achievement levels, purposively selected. Data were collected through test and semi-structured interviews. The results reveal distinctive profiles of mathematical understanding. High-achieving students were able to identify trigonometric concepts, use multiple representations, and flexibly relate trigonometric ratios to symbolic and contextual forms, although minor weaknesses in prerequisite algebraic knowledge were still evident. Medium-achieving students generally succeeded in routine and representational tasks but experienced conceptual confusion in determining reference angles and interpreting trigonometric ratios in non-routine situations. In contrast, low-achieving students exhibited fragmented understanding, characterized by difficulties in identifying relevant concepts, connecting word problem information to right triangle representations, and explaining their reasoning processes. These findings indicate that students' difficulties in trigonometry are not merely procedural but are strongly related to conceptual understanding and prerequisite knowledge.

Keywords: Mathematical Understanding; Vocational High School Students; Qualitative Case Study; Trigonometry.

I. INTRODUCTION

Mathematical comprehension ability is a basic ability that students must have, especially in learning mathematics. Mathematical comprehension is also important as a foundation for students to understand other abilities in learning mathematics (Afriansyah & Aini, 2025). Mathematical comprehension is also one of the learning objectives of each material presented by the teacher (Rerek, Hermiati, & Suprihatiningsih, 2025).

Mathematical understanding is a fundamental competence in mathematics learning, as it serves as the foundation for the development of other mathematical abilities such as reasoning, problem solving, and representation (NCTM, 2000; Kilpatrick, Swafford, & Findell, 2001; Sari, Supriadi, & Putra, 2022). Mathematical understanding is not merely the ability to memorize formulas, but involves connecting concepts, explaining meanings, using multiple representations, and flexibly applying concepts in various situations (Hiebert & Lefevre, 1986; Hidayat & Nuraeni, 2022). Students who rely primarily on procedural memorization often encounter difficulties when facing non-routine problems, whereas conceptual understanding supports meaningful learning (Skemp, 1976; Apiati, 2024).

The Regulation of the Minister of National Education (2006b) states that one of the goals in mathematics learning activities is to understand mathematics in the sense that students are expected to be able to understand mathematics well, not just rely on memorization.

In many classroom practices, mathematics learning is still delivered

informatively, positioning students as passive recipients of knowledge. Learning processes tend to emphasize imitation of examples and mastery of algorithms, which encourages students to memorize procedures without understanding their underlying meaning (NCTM, 2000; Murwanto, Qohar, & Sa'dijah, 2022). Consequently, many students can solve routine tasks but struggle to explain concepts, transform representations, or relate mathematics to contextual problems (Kilpatrick et al., 2001; Afriansyah & Arwadi, 2021).

In the context of vocational high schools, this condition becomes more critical. Mathematics in vocational education is often perceived merely as a supporting subject for productive competencies (Santoso & Ariyanti, 2023). Learning practices tend to emphasize practical calculation skills, while conceptual understanding receives less attention. In fact, vocational graduates are expected to face workplace situations that demand logical reasoning, modeling, and concept-based problem solving. Therefore, mathematical understanding is not only an academic objective, but also a cognitive foundation for solving technical and contextual problems in vocational fields.

Anggraeni (2013) said that mathematical comprehension skills are skills that must be developed in vocational high school students because they are in accordance with the objectives of mathematics learning, including understanding mathematical concepts, explaining the relationship between concepts, applying concepts, and having an interest in studying mathematics.

This view is consistent with the goals of mathematics education in vocational schools, which emphasize students' ability to understand concepts, explain relationships among ideas, and apply mathematics meaningfully in technical contexts (NCTM, 2000; Kilpatrick et al., 2001; Aisyah & Marlina, 2025).

One important topic in this context is trigonometry. Trigonometry plays a fundamental role in technical and vocational domains such as measurement, construction, mechanics, and automotive engineering. However, trigonometry is also recognized as one of the mathematical topics that students find difficult.

Trigonometry is one of the mathematical materials that are usually taught at the high school and vocational school levels. Trigonometry is one of the materials that is considered difficult by students (Nurafni et al., 2020; Imayanti & Jatisunda, 2025). Trigonometry is one of the important materials because trigonometry is one of the prerequisite materials for other materials. Mulyani and Muhtadi (2019) said that trigonometry is often used as a support for other materials.

Research indicates that trigonometry is often learned procedurally, focusing on formulas and special angle values, without developing a meaningful understanding of trigonometric ratios and their geometric interpretations (Weber, 2005; Moore, 2014; Nurwahid & Ashar, 2024).

Previous studies have reported that students' difficulties in trigonometry are not limited to computational errors, but are strongly associated with weaknesses in conceptual understanding,

representational competence, and conceptual connections. Students frequently misidentify reference angles, confuse the roles of triangle sides, and fail to translate word problems into right triangle models (Brown, 2006; Weber, 2005; Linda & Afriansyah, 2022). According to Duval (2006), such difficulties indicate problems in coordinating multiple mathematical representations, which is a core component of conceptual understanding.

Accordingly, this study aims to explore vocational high school students' mathematical understanding of trigonometric ratios. This research focuses on how students with different ability levels construct conceptual understanding, use representations, and interpret and apply trigonometric ratios in various types of problems. The findings are expected to provide empirical insights into the characteristics of vocational students' mathematical understanding and to inform the development of trigonometry instruction that emphasizes conceptual learning

II. METHOD

This study employed a qualitative research approach, as it aims to explore in depth students' mathematical understanding and thinking processes, which cannot be adequately captured through quantitative measurement alone (Sidiq & Choiri, 2019). The method used was a qualitative descriptive case study, which focuses on describing and interpreting phenomena as they naturally occur, particularly students' responses and

reasoning in solving trigonometry problems (Pandoyo & Sofyan, 2018; Sudjana & Ibrahim, 2007; Tajuddin et al., 2023).

The research subjects were drawn from three classes, namely XI TKRO-1, XI TKRO-2, and XI TKRO-3. Three students were selected for in-depth analysis, representing high, medium, and low mathematical ability levels based on students' academic records and the researcher's direct experience as a teaching practitioner at the school. The selection of only one student for each category was intentional and aligned with the qualitative case study design. These students were chosen not only because they represented different achievement levels, but also because they were also the most communicative and willing to articulate their thinking processes. This consideration enabled the researcher to obtain rich and meaningful qualitative data, particularly from interviews.

The indicators of mathematical understanding used in this study were adapted from established theoretical frameworks of conceptual understanding (NCTM, 2000; Kilpatrick, Swafford, & Findell, 2001). These indicators included: (1) identifying concepts verbally and in writing, (2) providing examples and non-examples, (3) using models, diagrams, and symbols to represent concepts, (4) transforming one form of representation into another, (5) interpreting concepts in various contexts, and (6) recognizing the properties and conditions of concepts. These indicators were operationalized into six trigonometry tasks and served as the analytical framework of this study.

Data were collected through written tests on trigonometric ratios and semi-structured interviews. The written test was designed to explore students' mathematical understanding based on the established indicators, while the interviews were conducted to examine students' reasoning, clarify their written responses, and identify sources of conceptual difficulties. Data analysis was carried out through data reduction, data display, and conclusion drawing. Triangulation between test results and interview data was applied to enhance the credibility of the findings.

III. RESULT AND DISCUSSION

From the results of the study conducted on three students, it was found that the three students had different comprehension abilities between one and the other. It can be seen that S1 has a comprehension ability above S2 and S3, and S2 has a comprehension ability above S3. S1 is able to understand the questions well and understand what steps must be taken to solve the problems given even though they are not perfect. S2 is also able to understand the questions well but S2 does not seem to understand some of the prerequisite materials from the trigonometry material or the material that has been taught before the trigonometry material. S2 also seems to have a little difficulty in determining the front side of the angle or the side of the angle. Widodo & Sujadi (2015) said that there are still many students who get low scores on trigonometry material. While S3 seems to have understood some of the question numbers but S3 does not really understand

what steps must be taken to solve the problems given.

Based on the research results, in general, the three students seemed to have understood the problems given. It can be seen that both S1 and S2 were able to know what was known and what was asked in the questions well. Meanwhile, S3, it can be seen in several question numbers that S3 was unable to write down what was known in the questions given. In question number 1 with the indicator of identifying concepts verbally and in writing through the activity of finding the concepts of sine, cosine, and tangent in a right triangle. Figure 1 is S1's answer to number one.

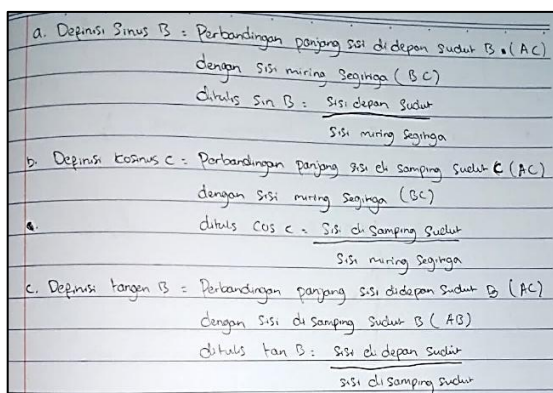


Figure 1. Answer S1 Question Number 1.

Figure 1 shows that S1 was able to understand the questions for the first indicator well so that the results of his work were correct. During the interview, nothing was found that made S1 not understand the questions given and the answers he wrote. The following is an excerpt from an interview with S1 regarding question number one.

P : For question number one, are you sure about your answer?

S1 : Yes

P : Do you understand the meaning of question number one?

S1 : Yes

Judging from the results of the answers and interviews, S1 was able to understand and explain well in detail and completely about what was meant by the question. It can be assessed that S1 has been able to achieve the first indicator, namely identifying concepts verbally and in writing through activities to find the concepts of sine, cosine, and tangent in right triangles. Furthermore, S2 has also been able to answer well related to the questions given in question number one, but S2's answer was not as complete as S1 and there were also errors in the answers that had been worked on by S2 where S2 seemed still confused about the definition of the front side of the angle and the side of the angle. While S3 did not answer the question in question number one. One of the causes of students' inability to define concepts is because students are used to working instantly without knowing the clear definition of what is in the question (Andriani, Suastika & Sesanti, 2017).

Arsalan, Rosita & Dewi (2019) in their research showed that in defining verbal and written is still lacking. Hewson & Thorley (Wijaya, Dewi, Fauziah & Afrilianto, 2018) said that understanding is a conception that is digested by students so that students can understand what is meant, find a way to express a concept and can explore what possibilities can be related to the conception. In this case, S1 can be said to understand because it can be seen from the answers given that S1 can correctly write a concept asked by the question while S2 seems unable to explore what if what is asked is another angle in

question number one. This is different from S3 who left his answer blank on question number one where it can be said that S3 cannot digest the concept in the definition of each trigonometric ratio.

In question number two with the indicator of identifying and creating examples and non-examples through the activity of finding the concept of sine, cosine and tangent in a right triangle, S1 can easily distinguish which statements are true and which are false. S1 also even works on the proof related to the statements contained in question number two correctly. In contrast to S2, S2 is able to correctly answer four of the six questions available in the question accompanied by proof of the answers given by S2 as seen in Figure 2.

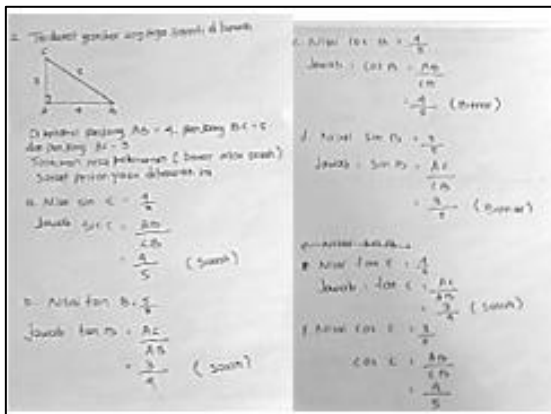


Figure 2. Answer S2 Question Number 2.

In Figure 2. S2 still seems confused in understanding the definition of the front side of an angle or the hypotenuse of an angle if there is a statement asking for more than one angle, especially in the tangent trigonometric ratio, which resulted in only four questions being answered correctly as stated in the interview for the first question. This is reinforced by the following interview summary:

P : Do you understand the meaning of

question number two?

S2 : Confused about number two

P : Confused how?

S2 : Part A I understand is looking for sin C. But if I'm looking for tan B, which part is in front? I'm confused.

P : For part f why don't you write whether the statement is true or false?

S2 : Oh yes

From the interview, S2 stated that he did not fully understand the questions given, resulting in inaccuracy when filling in the answers at certain points. In line with Sholihah (2018) in his research, he found that there were still many students who were not right in working on problems related to trigonometric comparisons. Meanwhile, S3 was able to do it correctly by distinguishing which statements were correct and which statements were incorrect by proving it the same as what S1 and S2 did. Mawaddah & Maryanti (2016) said that understanding is a process where students have the ability to provide an overview or example and are also able to provide an explanation. Both S1, S2, and S3 can provide an overview and explanation of the question given in number two, but there are still errors in the answers given by S2 so that only S1 and S3 can be said to fulfill indicator number two by providing a good explanation.

In question number three with indicators using models, diagrams and symbols to represent a concept through the activity of finding the concept of cosine in a right triangle, S1 can understand what is known in the question and can solve the question completely. However, there is an error in S1's answer where when simplifying the root form, S1 has not been able to do it correctly. Apart from the

trigonometry material being discussed, S1 does not seem to understand the prerequisite material of trigonometry, especially in the sub-chapter of trigonometry concepts in right triangles, namely root forms and powers. While in S2, some prerequisite materials in the trigonometry material also seem not to be fully mastered by S2. It can be seen from the answer given that S2 is still wrong in representing the known points in the question into a Cartesian graph which then forms a triangle when applied to the Cartesian graph even though the image only plays a role in helping students understand the symbols in the question and helping to find what the next steps are that must be done. Similar to S1, in the step of solving the root form, there was an error made by S2 in the calculation of the root form, but the error made was different from S1 where S1 made an error when simplifying the root form into standard form while S2 made an error in the step of adding the square values of the right side which resulted in both S1 and S2 being incorrect in answering question number three.

Sholihah (2018) in her research found that there are still many students who cannot perform operations on root forms. Susilo, Darhim, and Prabawanto (2019), said that students must be able to master the prerequisite material in order to understand the following materials. While S3, S3 was only able to complete the steps of drawing a Cartesian graph correctly and was able to understand the general definition of cosine asked in the question by looking at the Cartesian graph that he

had made, but S3 could not understand the next steps that must be taken to find the standard value of the cosine asked in the question. The following is S3's answer as seen in Figure 3.

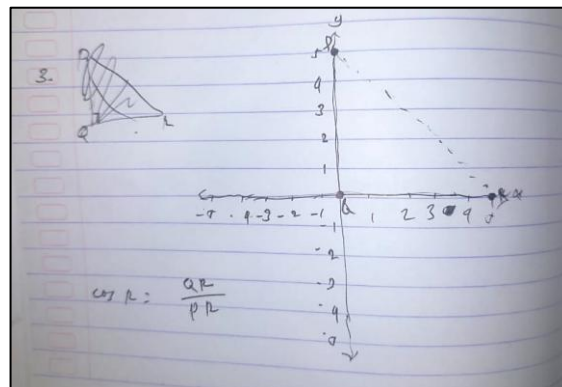


Figure 3. Answer S3 Question Number 3.

Figure 3 shows that S3 has not been able to fulfill the third indicator, namely using models, diagrams and symbols to represent a concept through the activity of finding the concept of cosine in a right triangle. This is reinforced by the following interview results.

- P : Do you understand the question in question number three?
 S3 : Understand
 P : Are you sure with your answer?
 S3 : Sure
 P : Explain your answer!
 S3 : Because the cosine is the side divided by the hypotenuse, so $\cos R$ is QR divided by PR .

In line with Sholihah (2018), in her research, she found that students were unable to connect the information in the questions with right triangles. In question number four with the indicator of changing one form of representation to another through the activity of finding the concept of sine and tangent in a right triangle, S1 was able to take the statement from the question correctly even though he did not

write down the steps to find the image. Figure 4 is S1's answer to number four.

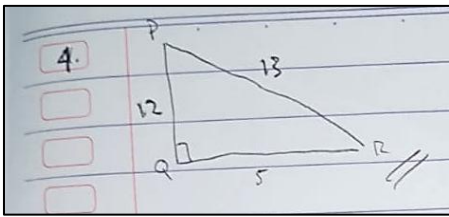


Figure 4. Answer S1 Question Number 4.

Figure 4 shows that S1 is able to change one form of representation into another form of representation for the problem in number four. This is reinforced by the results of the interview with S1 regarding question number 4.

- P* : Do you understand the meaning of question number four?
S1 : Understand
P : Are you sure with your answer?
S1 : Sure
P : Can you please explain?
S1 : Since $\sin P$ is equal to the opposite side of the angle divided by the hypotenuse, which is five thirteenths, and $\tan R$ is equal to the opposite side of the angle divided by the adjacent side of the angle, which is twelve fifths, then the shape of the triangle is PQ equals twelve, QR equals five, and PR equals thirteen.

Unlike S2, S2 first wrote down the steps correctly so that he found the triangle image asked by question number four. Here is S2's answer to question number four. While S3, S3 was able to understand the information contained in the question and was able to write down the meaning of the information briefly where S3 immediately applied the information he got from the question into what was asked by question number four, namely the triangle image.

Susilo, Darhim & Prabawanto (2019) said that students' difficulties in drawing

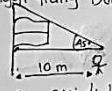
were influenced by their mathematical understanding. However, it can be seen that both S1, S2, and S3 can solve problem number four well even though the steps of the work are not the same between students. McCoy, Baker & Little (Hutagaol, 2013) said that one way to help students understand mathematics is to encourage students to find representations as a way of thinking to understand mathematical ideas. Indirectly, it can be said that the mathematical understanding of S1, S2, and S3 in problem number four is said to be good.

In question number five with the indicator of knowing various meanings and interpretations of concepts through activities to find the concepts of sine, cosine, and tangent in a right triangle, S1 can already understand what information is contained in the question. S1 can also process the information contained in the question and is able to solve the question with the correct and detailed steps. Similar to S1, S2 can also understand what information is contained in question number five. However, there are still errors in the answers made by S2 where S2 cannot convert the form of meters into centimeters, causing errors in calculations and ending with incorrect answers. Seen in Figure 5.

Dik : Tinggi badan anak = 1.0
Sudut elevasi = 45 derajat
Jarak anak dengan tiang = 10 m = 100 cm

Dit : Tinggi tiang bendera

Jawab :



$\tan 45^\circ = \frac{\text{sisi di depan sudut}}{\text{sisi di samping sudut}}$
 $1 = \frac{\text{sisi di depan sudut}}{100 \text{ cm}}$

Sisi di depan sudut = $100 \text{ cm} \times 1$
Sisi di depan sudut = 100 cm

Maka tinggi tiang adalah
 $100 \text{ cm} + \text{tinggi anak} = 100 + 150 \text{ cm}$
 $= 250 \text{ cm} = 2,5 \text{ m}$

Jadi tinggi tiang bendera adalah 2,5 m

Figure 5. Answer S2 Question Number 5.

Figure 5 shows that S2 is able to know what steps to take to solve problems such as type number five by understanding and recognizing the meaning or information contained in the question. S2 already understands the steps to be taken by finding the concept of tangent in the question and is able to understand how to find the total height of the pole by adding the height of the child and the length of the pole being searched for. However, during the interview, S2 did not seem to know that there was a slight error in his answer. The following is an excerpt from an interview with S2 regarding question number five.

- P : For question number five, are you sure with your answer?
- S2 : Sure
- S2 : The height of the flagpole is sought, the distance between the child and the flag is 10 m, first change it to cm to 100. The elevation angle is 45 degrees. The tan 45 value is 1, the side next to the corner is the distance between the child and the flag in cm, which is 100, just find the front side of

the corner $100 \times 1 = 100 \text{ cm}$. The value of the front side of the corner has been found, then add the height of the child. Then find the height of the pole.

It can be seen that S2 is able to achieve the fifth indicator, namely being able to recognize various meanings and interpretations of concepts through activities to find the concepts of sine, cosine, and tangent in right triangles. However, S2 does not understand how to change units of length where the material has been taught before trigonometry. In contrast to S3, S3 is only able to write down the information contained in the question without solving it. It can be seen that S3 is able to know the information in the question but cannot solve the question because he cannot find the next step to be taken. S3 can already recognize the information contained in the question but cannot interpret it into a trigonometry concept where S3 cannot find the concept of sine, cosine, or tangent contained in question number five.

Sholihah (2018) said that there are still many students who find it difficult to connect questions with trigonometry concepts in right triangles. This is supported by the opinion of Arikunto (2009) who said that some students present concepts well in representational form, but there are students who still make mistakes when presenting them. Andriani, Suastika & Sesanti (2017) said that students still do not understand how to apply concepts to the problems given and also students' understanding of the questions is still lacking. Research conducted by Suraji, Maimunah and Saragih (2018) stated that

some students are still confused about understanding questions to be converted into mathematical models causing students to misinterpret the questions asked.

In question number six with the indicator of identifying the properties of a concept and recognizing the conditions that determine a concept through the activity of finding the concept of sine, cosine, tangent, cosecant, secant, and cotangent in a right triangle, S1 can understand well the definition and properties of each trigonometric ratio so that S1 can solve problem number six part a correctly. S1 can also know the initial steps that must be taken where he must find the value of one of the unknown sides with the Pythagorean theorem. However, just like number three, it seems that S1 has not understood one of the prerequisite materials of the trigonometry material, especially in the trigonometry sub-chapter on right triangles, namely the material on exponents and roots so that S1 does not complete his answers by rationalizing the form of root fractions from several answers he obtained. Apart from question number six part a, it seems that S1 cannot understand the form of question number six part b so that S1 does not work on the question.

In contrast to S2, although S2 can understand the solution of several trigonometric ratios, it seems that S2 cannot understand the wording of the question well. This is proven by the incomplete answer to question number six part a that was done by S2. S2 only answered 3 of the 5 trigonometric ratios asked by the question. Similar to S1, S2 does not seem to understand the form of

the equation given by question number six part b, which causes S2 to make a mistake in solving the problem. In contrast to S3, S3 does not seem to understand the question asked, Figure 6 is S3's answer to question number 6.

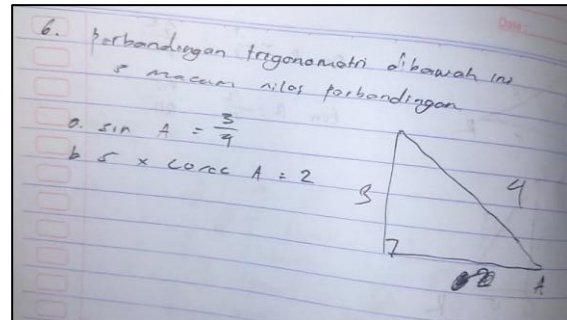


Figure 6. Answer S3 Question Number 6.

Figure 6 shows that S3 has not been able to fully understand the question asked in question number 6, which causes S3 to be unable to answer the question. The following is an excerpt from an interview with S3 regarding question number 6.

- P : Are you sure with your answer?
S3 : Not sure, that's also random
P : Which part do you not understand?
S3 : Five types of comparison
P : What is the purpose of the question, can you understand it?
S3 : Do not understand

From the interview results, S3 did not answer question number six for both part a and part b. S3 was only able to represent the sine value into a right triangle, where this step should be the first step to solve question number six part a. Jusniani (2018) said that there are still many students who make mistakes in solving questions related to indicators of identifying the properties of concepts and recognizing the conditions that determine a concept. However, Sona & Hartoyo (2018) said that students' low understanding of indicators of identifying the properties of a concept and recognizing

the conditions that determine a concept is caused by a lack of initial knowledge about the properties and conditions for forming a concept.

IV. CONCLUSION

Based on the results of this study, students' mathematical understanding of trigonometry varied across individuals and across indicators, reflecting different profiles of conceptual development. Analysis based on six indicators of mathematical understanding showed that students' strongest performance was in transforming representations, while their greatest difficulties were in identifying properties and conditions of trigonometric concepts.

High-ability students demonstrated relatively coherent conceptual understanding supported by appropriate use of representations, although still constrained by weaknesses in prerequisite algebraic knowledge. Moderate-ability students showed partial conceptual construction with frequent confusion related to reference angles and contextual interpretation. Low-ability students exhibited fragmented understanding, limited to surface-level engagement without meaningful conceptual integration.

These findings indicate that students' difficulties in trigonometry are not merely procedural, but are rooted in conceptual gaps and insufficient integration of prerequisite knowledge. Therefore, trigonometry instruction should emphasize conceptual reconstruction, explicit treatment of reference angles, coordination of multiple representations,

and reinforcement of prerequisite concepts to foster deeper mathematical understanding.

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AUTHOR'S BIOGRAPHY

Dr. Irmawati Liliana Kusuma Dewi, M.Pd.



Born in Sragen, on June 26, 1980. Lecturer at the Mathematics Education Study Program at Universitas Swadaya Gunung Jati. Studi S1 Mathematics Education, Universitas Negeri Semarang,

Semarang, graduated in 2003; Master of Mathematics Education, Universitas Negeri Semarang, Semarang, graduated in 2013; and Doctoral Degree in Mathematics Education, Universitas Negeri Semarang, Semarang, graduated in 2023.

Dr. Cita Dwi Rosita, M.Pd.



Born in Cirebon, on September 16, 1981. Lecturer at the Mathematics Education Study Program at Universitas Swadaya Gunung Jati. Studi S1 Mathematics Education, Universitas Swadaya Gunung Jati, Cirebon, graduated in 2005; Master of Mathematics Education, Universitas Negeri Semarang, Semarang, graduated in 2010; and Doctoral Degree in Mathematics Education, Universitas Pendidikan Indonesia, Bandung, graduated in 2018.

Dr. Much. Subali Noto, S.Si., M.Pd.



Born in Pekalongan, on Juni 2, 1986. Lecturer at the Mathematics Education Study Program at Universitas Swadaya Gunung Jati. Studi S1 Mathematics Departement, Universitas Negeri Semarang, Semarang, graduated in 2008; Master of Mathematics Education, Universitas Negeri Semarang, Semarang, graduated in 2010; and Doctoral Degree in Mathematics Education, Universitas Pendidikan Indonesia, Bandung, graduated in 2022.

Farhan Ferdiansyah, S.Pd.



Born in Cirebon, on Juni 6, 1997. Bachelor of Education Mathematics, Universitas Swadaya Gunung Jati in 2017.