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Analyzing Trigonometry Learning Obstacles from a Mathematical Literacy Perspective

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Abstrak

Penelitian ini bertujuan menganalisis hambatan belajar siswa yang diberikan soal trigonometri dalam literasi matematis. Hambatan belajar merupakan faktor yang harus diungkap agar prestasi belajar optimal. Materi trigonometri memuat identitas jumlah dan selisih sudut; identitas sudut ganda; identitas sudut paruh; identitas perkalian ke penjumlahan; serta identitas penjumlahan ke perkalian. Materi trigonometri diberikan berdasarkan literasi matematis. Literasi matematis berdasarkan 5 indikator yaitu (1) membuat model matematika berupa tabel, gambar, grafik, diagram maupun ekspresi matematika yang memudahkan menyelesaikan permasalahan, (2) memilih dan membandingkan strategi untuk memperoleh penyelesaian, (3) menuliskan jawaban dalam perhitungan yang logis, (4) menggunakan penalaran untuk mengaitkan informasi yang diperoleh dari suatu permasalahan dengan konsep yang dimiliki, dan (5) menggunakan atau memanipulasi rumus atau prosedur dalam penyelesaian permasalahan. Penelitian ini dilakukan pada siswa kelas XI MIPA 6 SMAN 1 Palimanan menggunakan metode kualitatif dengan menganalisis hasil jawaban siswa. Hasil Penelitian ini menunjukan hambatan belajar siswa pada trigonometri dalam literasi matematis terdapat pada indikator (3), (4), dan (5).

Kata Kunci: Interpretatif, Kualitatif, Manipulasi prosedur, Mengaitkan informasi, Perhitungan logis

Abstract

The focus of this research is to examine the challenges that students face when attempting trigonometry questions in mathematical literacy. These learning obstacles need to be addressed in order to maximize the students' learning achievements. The trigonometry material that is presented in mathematical literacy includes various identities, such as the sum and difference of angles, double angle identity, beak angle identity, multiplication to addition identity, and addition to multiplication identity. Mathematical literacy is based on 5 indicators, namely (1) making mathematical models in the form of tables, pictures, graphs, diagrams, and mathematical expressions that make it easier to solve problems, (2) choosing and comparing strategies to obtain solutions, (3) writing answers in logical calculations, (4) use reasoning to associate information obtained from a problem with the concept that is owned, and (5) use or manipulate formulas or procedures in solving problems. In this research, a qualitative method was utilized to analyze the answers provided by students from class XI MIPA 6 SMAN 1 Palimanan. The findings of this

study indicate that students face learning challenges in trigonometry when it comes to mathematical literacy, specifically in indicators (3), (4), and (5).
***Keywords**: Associating information, Interpretative, Logical calculations, Manipulation of procedures, Qualitative*

Introduction

Trigonometry is a challenging mathematical subject due to the multiple formula derivations and identities involved. In addition to the numerous forms and identities, there are also various conditions to consider, such as quadrant positions, angles, and radians. Students are also required to have a solid understanding of prerequisite material, such as the Pythagorean theorem, and be able to apply modeling techniques with other mathematical concepts, including quadratic equations and other relationships. Consequently, students often encounter numerous obstacles when learning trigonometry.

Obstacles to learning are one of the factors of low student achievement. According to Ratnaningsih (2020), learning achievement is mastery of knowledge or skills that are developed through subjects, usually indicated by test scores or grades given by the teacher. Learning obstacles are obstacles or difficulties faced by students when learning which results in the results of learning being carried out not optimal (Subroto & Sholiha, 2018; Balkist, 2019). Khaerunisa et al. (2022) argue that learning obstacles are students' difficulties in learning material in several parts and these difficulties are almost the same as those experienced by other students. In addition, Fauziah (2022) revealed that learning obstacles can occur because students do not understand well and the learning objectives and the content of the material being studied. From the several definitions of obstacles described, it can be concluded that learning obstacles are obstacles experienced by students in learning resulting in low learning achievement.

Obstacles to learning trigonometry generally occur due to errors in the calculation process or skills in procedures (Mensah, 2017; Rosjanuardi & Jupri, 2022). Obstacles to learning trigonometry because students have not been able to relate one concept/principle to another, in other words, they have a low understanding of the concept (Balkist, 2019; Erlisa & Prabawanto, 2019; Fauziah, 2022; Fauziah & Puspitasari, 2022; Gunadi et al., 2022; Khaerunnisa et al ., 2022; Rahmawati et al., 2021; Subroto & Sholiha, 2018; Sukmawati & Jumarniati, 2019). In addition to students' lack of understanding of concepts, obstacles to learning Trigonometry are due to erroneous determination of formulas and solving non-

routine questions (Jatisunda & Nadi, 2019; Insani & Kadarisma, 2020; Gunadi et al., 2022). Other obstacles were also found due to a lack of understanding of connecting the material of one sub-chapter with other sub-chapters (Janah et al., 2018; Sakah et al., 2019; Saputra et al., 2021).

Mathematical literacy is a must-have ability for current students in the 21st century. Mathematical literacy is one of the benchmarks for measuring the success of education in a country. The success evaluation was carried out by *the Organization for Economic Cooperation and Development* (OECD) through *the Program for International Student Assessment* (PISA) which has been held since 2000 until now and is held every three years. One of the three abilities evaluated is in the form of mathematical literacy.

The OECD explains that mathematical literacy is the ability of someone to formulate, use, and interpret mathematics in various situations. Mathematical literacy includes mathematical logic and the use of mathematical concepts, procedures, facts, and devices to describe, describe, and estimate a phenomenon (Kemendikbud, 2019). Another definition related to mathematical literacy, Sari (2015) defines the use of reasoning, concepts, facts, and mathematical tools in solving everyday problems; Kurniawati et al. (2020) define the ability to understand problems related to mathematics and can be applied in everyday life; Husniati et al. (2020) the ability to make rational and logical judgments and decisions; Yudiawati et al . (2021), the ability to formulate, employ and interpret in various contexts; Ugler et al. (2022) the ability to use mathematics in solving problems in life; Andriyani & Wilujeng (2022) the ability to analyze, argue and communicate ideas effectively in solving mathematical problems; Supianti et al. (2022) use mathematical knowledge to solve and interpret problems.

Based on the understanding of mathematical literacy from some of the opinions above, it can be concluded that mathematical literacy is the ability to model problems in everyday life into mathematical forms, the link between information, perform logical calculations, manipulate methods or procedures, and choose the right strategy so that it can solve a problem. that problem. Mathematical literacy is an important ability that students must have because this ability uses mathematics to solve problems in everyday life (Kusumawardani et al. 2018; Answar, 2018; Muritiyasa & Perwita, 2020; Kurniati et al ., 2020; Husniati et al., 2020;

Ulger et al ., 2022; Aulia & Prahmana, 2022; Andriyani & Wilujeng, 2022; Hardianti & Desmayanasari, 2022).

In order to measure mathematical literacy, indicators must be established to gauge achievement. For the purpose of this study, the indicators of mathematical literacy are based on the definition by Hardianti & Desmayanasari (2022). These indicators include: (1) Creating mathematical models through the use of tables, pictures, graphs, diagrams, or mathematical expressions to facilitate problem-solving, (2) comparing and selecting strategies for arriving at solutions, (3) presenting answers using logical calculations, (4) utilizing reasoning to connect information obtained from a problem with previously learned concepts, and (5) applying formulas or procedures to solve problems.

As previously mentioned, trigonometry poses various learning obstacles, while mathematical literacy is a crucial skill to possess. Therefore, this research aims to analyze the learning difficulties that students encounter when studying trigonometry in the context of mathematical literacy. What sets this study apart from others is that it specifically focuses on analyzing the obstacles that arise during the learning process of trigonometry in mathematical literacy, as opposed to examining learning obstacles from an epistemological and didactical structural perspective or based on mathematical abilities such as mathematical understanding, mathematical reasoning, and learning styles.

Method

The research methodology employed in this study is qualitative research with an interpretive approach. The interpretive approach involves analyzing data through the process of creating research transcripts, repeatedly reviewing the transcripts, and providing exploratory comments (Hadyani & Indriana, 2017). The data for this study were obtained from the test results of 35 students in class XI MIPA 6 at SMAN 1 Palimanan, who had previously studied trigonometry material. The participants were selected using purposive sampling, taking into account the normal distribution of mathematical abilities based on the results of previous tests. The test consisted of five questions related to trigonometry in the context of mathematical literacy. The indicators used to assess mathematical literacy were based on the framework outlined by Hardianti & Desmayanasari (2022).

The questions given represent each trigonometry material in the sum and difference of angles chapter. The rubric for evaluating trigonometry questions in mathematical literacy is shown in Table 1.

Table 1. Rubric for evaluating questions with mathematical literacy indicators

No	Question	Indicator
1	If $\sin a = \frac{12}{13}$ and $\cos b = -\frac{4}{5}$, then the value of$\sin(a-b) =$ ...	1. Students can determine the formula to be used: $\sin(a-b) = \sin a \cos b - \sin b \cos a$ 2. Students can make strategies to obtain solutions: First, find the value of $\sin b$ and $\cos a$ 3. Students can to perform calculations: - Can operate addition and multiplication in the form of fractions and roots - Making answer prediction a condition such as if in quadrant I or II, and b in quadrant I then it is possible $a-b$ to be in quadrant I 4. Students can reason to associate information with the concepts they have: $\sin a$ is positive than a in quadrants I or II, $\cos b$ negative values then b in quadrants II and III
2	If $\cos \alpha = \frac{3}{5}$, then the value of $\cos 2\alpha$ is...	1. Students are able to determine the formula to be used: $\cos 2\alpha = \cos^2 a - \sin^2 a = 1 - 2\sin^2 a = 2\cos^2 a - 1$ 2. Students can create strategies to obtain solutions: - If using the formula $\cos 2\alpha = \cos^2 a - \sin^2 a$ or $\cos 2\alpha = 1 - 2\sin^2 a$ then first find the value $\sin a$ - If using a formula $\cos 2\alpha = 2\cos^2 a - 1$ then directly substitute the value $\cos a$ 3. Students can make logical calculations: - Can operate addition and multiplication of fractions and roots - Making the answer prediction a $\cos a$ positive value requirement, quadrants I or IV results $2a$ in quadrants I, II, III, or IV, so $\cos 2a$ they can be positive or negative 4. Students can provide reason to associate information with the concept they have: $\cos \alpha$ is positive then a in quadrant I or IV, if you look for $\sin a$ is positive value e in quadrant I and negative in quadrant IV 5. Students can use or manipulate formulas or procedures: If students do not know the formula that will be used, students can use the basic formula for the identity of addition and difference of angles and connect the Pythagorean identity

No	Question	Indicator
		$\cos 2a = \cos(a + a) = \cos a \cos a - \sin a \sin a$
3	Jika $cos\ a = \frac{4}{5}$, then the value of$tan\left(\frac{a}{2}\right) =$ …	1. Students can determine the formula to be used: $tan\left(\frac{a}{2}\right) = \pm\sqrt{\frac{1-\cos a}{1+\cos a}} = \frac{1-\cos a}{\sin a} = \frac{\sin a}{1+\cos a}$ 2. Students can creacanes to obtain solutions: - If the student chooses the formula $tan\left(\frac{a}{2}\right) = \pm\sqrt{\frac{1-\cos a}{1+\cos a}}$ does not require other elements such as the value of the sine tangent, if you choose another formula then you need to find the value $\sin a$ - If the student chooses the formula $tan\left(\frac{a}{2}\right) = \frac{1-\cos a}{\sin a}$ atau $tan\left(\frac{a}{2}\right) = \frac{\sin a}{1+\cos a}$ Students must determine the value of $\sin a$ 3. Students can perform logical calculations: - Can operate addition and multiplication of fractions and roots - $cos\ a$ If it is positive, it is in quadrant I or IV which results $\frac{a}{2}$ in quadran or III, so $tan\left(\frac{a}{2}\right)$it is positive 4. Students can associate information with the concepts they have: $\cos a$ has a positive value then a is in quadrant I or IV, if it requires a value $\sin a$ then it has a positive $\sin a$ value in quadrant I and a negative value in quadrant IV. 5. Students can use or can formulas or procedures: If students do not know the formula that will be used students can use the basic formula for addition and difference of angles and Pythagorean identities.
4	Value ofsin 75° . sin 15° = ⋯	1. Students can determine the formula to be used: $sin\ a\ .\ sin\ b = \frac{1}{2}[\cos(a-b) - \cos(a+b)]$ 2. Students can create strategies to obtain solutions: - Solving with the multiplication identity formula for addition - Solve with the identity formula for the sum and difference of angles 3. Students can perform logical calculations: perform addition and subtraction of fractions - Making predictions a requirement for a $\sin 75°$ as a positive answer and $\sin 15°$ as a positive value, then multiplying two positive numbers produces a positive

No	Question	Indicator
		number 4. Students are able to reason to associate information with the concept they have: The questions will be directed to the sum or difference of the angles to be special angles of Trigonometry 5. Students can use or manipulate formulas or procedures: - If students do not know the formula that will be used, students can use the basic formula for the identity of addition and angle differences - Manipulate procedures such as $\sin 75° . \sin 15° = \sin(90° - 15°) \sin 15°$ $\sin 75° . \sin 15° = \cos 15° \sin 15° = \frac{1}{2} . 2 \cos 15° \sin 15°$ $\sin 75° . \sin 15° = \frac{1}{2} . \sin(2.15°) = \frac{1}{2} . \sin 30° = \frac{1}{2} . \frac{1}{2} = \frac{1}{4}$
5	Value of $\cos 135° - \cos 105° = \cdots$	1. Students can determine the formula to be used: $cos\ a - cos\ b = -2 \sin\left(\frac{a+b}{2}\right) \sin\left(\frac{a-b}{2}\right)$ 2. Students can make strategies to obtain solutions: - Solving with the identity formula for addition to multiplication - Solve with the formula for the identity of the sum and difference of angles 3. Students can perform logical calculations: Can perform addition and subtraction operations with fractions and roots 4. Students are able to reason to associate information with the concept they have: The questions will be directed to the sum or difference of the angles to be special angles of Trigonometry 5. Students are able to use or manipulate formulas or procedures: - If students do not know the formula that will be used students can use the basic formula for the identity of addition and difference of angles - Able to manipulate known angles into special angles of Trigonometry

After the data on the results of student answers are collected, the data is analyzed based on indicators of mathematical literacy. The percentage of students answering each question is interpreted into a range of categories. The percentage category of students able to master each indicator of mathematical literacy can be seen in Table 2.

Table 2. Categories of mathematical literacy

Percentage of students	category
0%	Unable
1% - 25%	Less fortunate
26% - 50%	Quite capable
51% - 75%	Capable
76% - 100%	Very Capable

Results and Discussion

The following is a test result of 5 trigonometry questions which contain 5 indicators of mathematical literacy given to respondents.

Problem number 1: sum and difference of angles

Student answers for number 1, 91% of students know the formula of $\sin(a-b) = \sin a \cos b - \cos a \sin b$. Of the 91% of students, students can also determine a strategy to solve the problem by first finding the value of $\cos a$and $\sin b$ which is then substituted into the formula $\sin(a-b)$. Only 9% of students are wrong in carrying out calculation procedures. However, only 9% of students also identified the questions, the questions were not given a description of the coordinates odesdescribedudents should reason that if $\sin a$ the value is positive then the possible angle $a$is in quadrant 1 or 2, $\cos b$ if it is negative then the possible angle $b$is in quadrant 2 or 3. It is possible that if the angle is a in quadrant 1 and $b$in quadrant 2 and so on, until a more precise result $\sin(a-b) = \frac{-63}{65}$ or $\sin(a-b) = \frac{-33}{65}$. Students only answer up to $\sin(a-b) = \frac{-63}{65}$it. The following Figures 2a and 2b are related b several student answers in number 1.

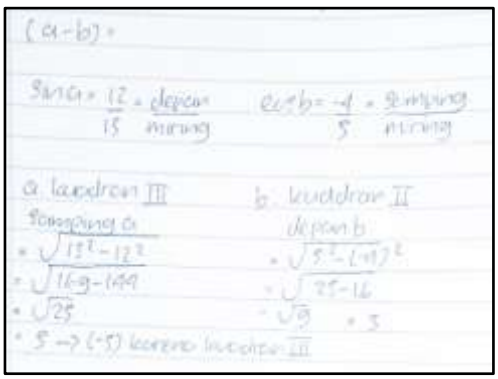
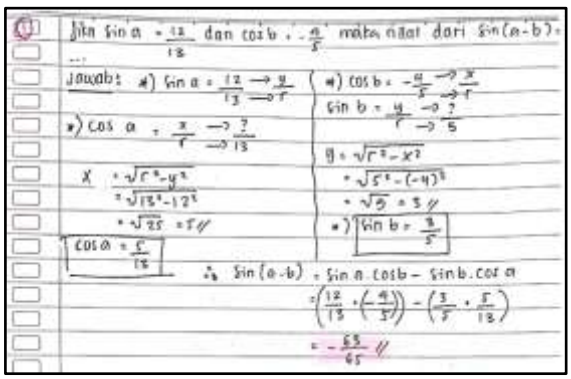


Figure 2a.
Don't know formulas



Picture. 2b
Don't associate information

From the results of students' answers to question number 1, the mistake is that students are still low in understanding the concept (Balkist, 2019; Erlisa & Prabawanto, 2019; Fauziah, 2022; Fauziah & Puspitasari, 2022; Gunadi et al., 2022; Khaerunnisa et al., 2022; Rahmawati et al., 2021; Subroto & Sholiha, 2018; Sukmawati & Jumarniati, 2019), students do not apply comparative values to quadrant positions so they do not find a variety of solutions.

Problem number 2: double angles

Based on the results of student answers, there were 9% of students forgot the formula from $\cos 2\alpha$, resulting in 9% of students also being unable to continue calculations and determine the strategy that must be carried out in solving question number 2. There were 11% of students who knew the formula and could determine strategies to answer questions but were mistaken in carrying out the operating procedure in the form of fractions. Up to 20% of students can use reasoning and manipulate formulas, where students only know formulas $\cos(a+b) = \cos a \cos b - \sin a \sin b$, but students manipulate shapes $\cos 2\alpha$to become $\cos(a+a)$, which then produces $\cos 2\alpha = \cos^2 a - \sin^2 b$. Because it is known only $\cos \alpha$then students relate that information $\sin^2 b = 1 - \cos^2 a$and finally produce $\cos 2\alpha = 2\cos^2 a - 1$. Student answers for number 2 can be seen in Figures 3a and 3b .

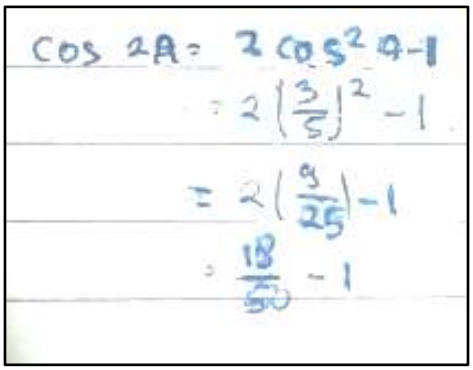


Figure 3a.
Erroneous in carrying out procedures fractional operations

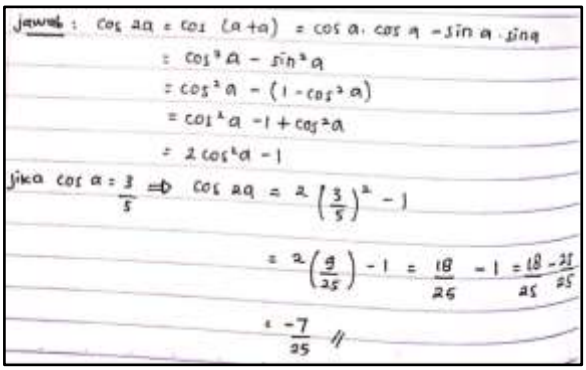


Figure 3b.
Do not link information

In general, the mistakes that occur in student answers to question number 2, many students make mistakes in the calculation process and are less skilled in procedures due to errors in the calculation process or skills in the procedure (Mensah, 2017; Rosjanuardi & Jupri, 2022).

Problem number 3: beak angle

Based on student answers, there were 37% of students forgot the formula from $tan\left(\frac{a}{2}\right)$, at 6% could not determine the strategy for answering the questions even though they knew the formula $tan\left(\frac{a}{2}\right)$. Furthermore, from those who already know the formula, there are 3% of students who are wrong in operating fractions. There are no students who identify the coordinates of $\frac{a}{2}$the possibility $cos\, a$ of positive value. $a$in quadrants 1 or 4 results in $\frac{a}{2}$being in quadrants 1 or 2, then $tan\left(\frac{a}{2}\right)$it is positive. Some student answers can be seen in Figure 4.

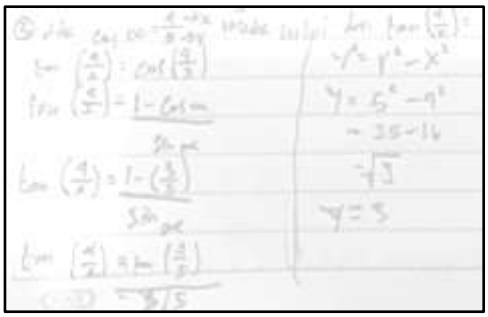


Figure 4a.
Don't know formulas

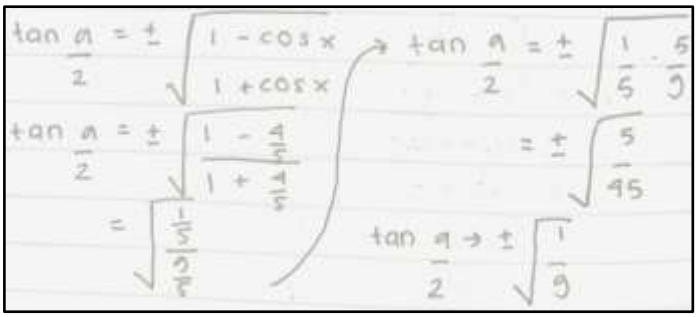


Figure 4b.
Don't associate information

From the overall results of student answers in number 3, things that are wrong in answering questions are generally wrong using formulas and difficult to solve non-routine questions (Jatisunda & Nadi, 2019; Insani & Kadarisma, 2020; Gunadi et al., 2022), where the elevation angle is usually given a descrdescribedobtuse angle.

Problem number 4: multiplication to addition

The results of the answers to question number 4, 20% of students did not know the formula from the identity of multiplication to addition, then there were 6% of students who did not know what to do even though they already knew the formula used. There are 11% of students unable to perform addition operations correctly. There are 37% of students able to make multiplication formulas to sums from the addition and difference of Trigonometry angles, then manipulate angles that are known to be special angles in Trigonometry. The following are Figures 5a and 5b for the answers from several students in number 4.

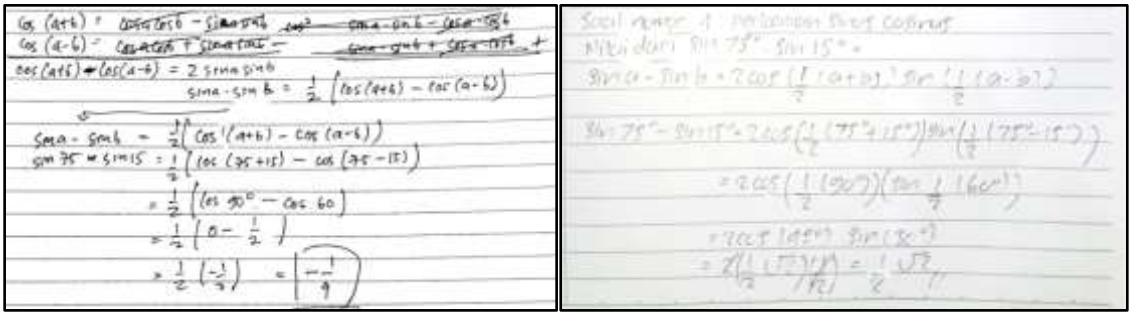


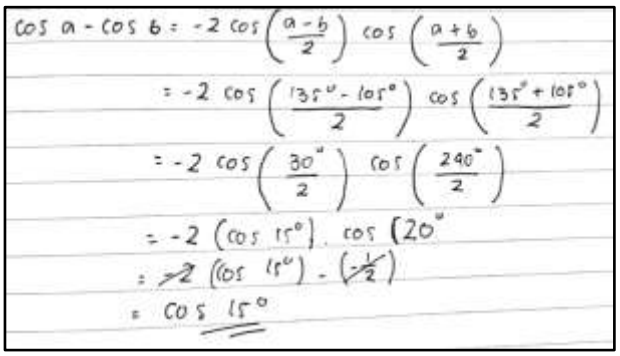
Figure 5a.
Mistakenly using the formula

Figure 5b.
Erroneous using the formula

In general, the mistake that occurred in answering question number 4 was to use the wrong formula (Jatisunda & Nadi, 2019; Insani & Kadarisma, 2020; Gunadi et al., 2022) and due to errors in the calculation process or skills in the procedure (Mensah, 2017; Rosjanuardi & Jupri, 2022).

Problem number 5: Addition to multiplication

Based on student answer number 5, 46% of students did not know the formula used in the problem, and 5% of students even thought they knew the formula but could not proceed to the calculations. As many as 29% of students were unable to perform calculation operations on fractions and roots correctly and only 26% of students answered correctly because they could change known angles into trigonometry special angles. Some of the results of student number 5's answers can be seen in Figures 6a and 6b.



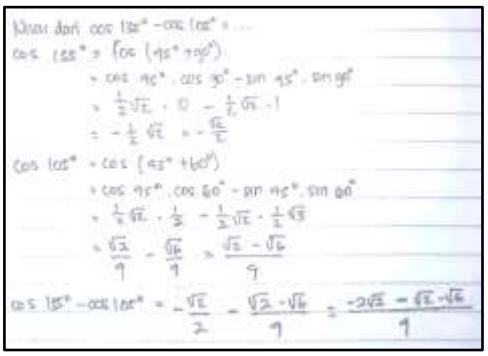


Figure 6a.
Erroneous in using the

Figure 6b.
wrong formula in the calculation process

The misunderstanding of student answers in number 5 can be seen in general that they are wrong in using the formula (Jatisunda & Nadi, 2019; Insani & Kadarisma, 2020; Gunadi et al., 2022) and due to errors in the calculation process or skills in the procedure (Mensah, 2017; Rosjanuardi & Jupri, 2022).

Furthermore, the following are the results of the analysis of Trigonometry learning obstacles based on mathematical literacy indicators:

1. **Creating a mathematical model can be in the form of tables, pictures, graphs, diagrams, or mathematical expressions that can make it easier to solve problems**

   In question number 1 the percentage of students fulfilling this indicator is 97%, question number 2 is 91%, question number 3 is 63%, question number 4 is 80%, and

question number 5 is 54%, then the average percentage of students knows the formula which will be used to solve a Trigonometry problem for 77% of students. With the number of percentages of these students, it can be interpreted that students can make mathematical models which can be in the form of tables, pictures, graphs, diagrams, or mathematical expressions which can make it easier to solve problems.

2. **Select and compare strategies to obtain a solution**

   Based on student answers, it can be obtained that fulfill this indicator, in question number 1 is 97%, question number 2 is 91%, question number 3 is 57%, question number 4 is 74%, and question number 5 is 49%. The average percentage of students fulfilling indicator 2 is 74%, it can be interpreted that students are ablecanand compare strategies to obtain a solution.

3. **Write down the answers in a logical calculation**

   Based on the results of the student's answers, 94% of the students met the indicators in question number 1, 80% of students in question number 2, 54% of students in question number 3, 66% of students in question number 4, and 20% of students in question number 5. On this indicator, the average percentage of students who comply is 63%. Thus it can be interpreted that students are quite capable of writing answers in logical calculations.

4. **Using reasoning to associate information obtained from a problem with the concept that has been owned**

   From the results of student answers, which met this indicator, 0% of students in question number 1, 20% in question number 2, 0% in question number 3, 37% in question number 4, and 23% in question number 5. On average only 16% of students meet this indicator, from these results it can be interpreted that, students are less able to use reasoning to associate information obtained from a problem with the concept they already have.

5. **Using or manipulating formulas or procedures in solving problems.**

   On this indicator, the answers fulfilled were 20% of students on question number 2, 0% of students on question number 3, 34% of students on question number 4, and 26% of students on question number 5. The average student's answers from the four questions meet the indicator of 20%, for the ability of students in this indicator it can be interpreted

that students are less able to use or manipulate formulas or procedures in solving problems.

Conclusion

Based on the students' answers to the five trigonometry questions, it was found that indicators 1 and 2 were not problematic for students. Students were able to create mathematical models in the form of tables, pictures, graphs, diagrams, or mathematical expressions to facilitate problem-solving, and they were also able to select and compare strategies to find solutions. However, the challenges in learning trigonometry material were identified in indicators 3, 4, and 5. Although students were reasonably proficient in writing answers using logical calculations, they faced difficulties in using reasoning to connect the information acquired from a problem with the concepts they have learned, and they also struggled to apply formulas or procedures to solve problems.

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