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## Profile of Students' Mathematical Problem-Solving Ability in Real-Context Trigonometry Problems: A Qualitative Study

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### ABSTRACT

Mathematical problem-solving ability is an important competency that supports students in applying mathematical concepts to real-life situations. However, students often encounter difficulties in solving contextual problems, particularly in trigonometry. This study aimed to describe students' mathematical problem-solving abilities in solving real-life context trigonometry problems based on Polya's problem-solving stages. A qualitative approach was employed involving three tenth-grade students representing high, moderate, and low mathematical ability levels. Data were collected through written tests and interviews and analyzed according to four stages of problem solving: understanding the problem, devising a plan, carrying out the plan, and looking back. The results showed that students' problem-solving profiles varied according to their mathematical ability. High-ability students performed well in most stages but lacked thorough verification of answers. Moderate-ability students were able to solve problems appropriately but showed weaknesses in reflection. Low-ability students experienced difficulties in understanding contextual information and selecting suitable strategies. Overall, the looking-back stage was the most challenging for all students. The study concludes that mathematical ability shapes distinct problem-solving profiles, with looking back remaining the weakest stage overall. These findings imply that trigonometry instruction should strengthen students' verification skills and their ability to connect solutions with real-life situations.

## 1. Introduction

Mathematics is a compulsory subject for all students from elementary school, junior high school, and senior high school through higher education. Under the Regulation of the Minister of Education, Culture, Research, and Technology Number 12 of 2024, as amended by the Regulation of the Minister of Primary and Secondary

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Education Number 13 of 2025, mathematics is positioned not only as a compulsory subject but also as an elective subject for students (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2024; Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2025). Within this curriculum framework, mathematics is viewed as knowledge about logical thinking that underlies the development of modern technology and is greatly needed in human life. Mathematics is therefore learned not merely to be understood, but also as a tool for building understanding, training ways of thinking, and solving problems in everyday life.

One of the goals of mathematics learning in the curriculum is to develop problem-solving ability, which includes understanding problems, designing mathematical models, solving the models, and interpreting the solutions obtained. The National Council of Teachers of Mathematics (NCTM) likewise emphasizes problem solving as a key ability in mathematics learning (National Council of Teachers of Mathematics, 2000), and problem solving is widely regarded as a central goal of mathematics learning (Kohen & Nitzan-Tamar, 2022). Problem solving means finding a way out of a difficulty, finding a way around an obstacle, and attaining a desired goal with appropriate means (Polya, 1957). Pólya (1957) stated that mathematical problem solving consists of four stages, namely understanding the problem, devising a plan, carrying out the plan, and looking back. Using these stages helps researchers identify students' thinking processes at each step of problem solving (Aisy et al., 2021), and international research shows that students' problem-solving profiles based on Polya's stages tend to differ according to their level of mathematical ability, making it important to examine each ability category in depth (Riyadi et al., 2021).

Evidence from the field shows that students' problem-solving ability is still relatively low. The results of the Programme for International Student Assessment (PISA) show that Indonesian students still have difficulty solving problems that require higher-order reasoning, and the declining scores from 2015 to 2022 indicate that the problems of mathematics learning in Indonesia have not been resolved comprehensively. OECD (2023) data show that the average mathematical literacy score of Indonesian students continued to decline over the last three PISA cycles, from 386 in 2015 to 379 in 2018 and 366 in 2022, with an increasingly wide gap relative to the average score of OECD countries (490, 489, and 472 in the same years). Studies tracing Indonesian students' mathematical literacy over the last decade also show a stagnant and even declining trend, particularly in reasoning and solving contextual problems (Aisyah & Juandi, 2022).

This condition is also reflected in the 2022–2025 Minimum Competency Assessment (Asesmen Kompetensi Minimum, AKM) results for SMA Negeri 1 Banawa reported in the Education Report Card (Rapor Pendidikan), which show that only 33.33% of students reached the minimum competency in numeracy, especially in solving contextual problems. This is in line with Mahmud and Pratiwi (2019), who found that students' numeracy literacy is still low and that students have difficulty understanding the context and interpreting solutions. Interviews with students revealed that they experience obstacles when working on word problems or problem-based tasks because they are accustomed to standard

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procedures. According to Pratiwi & Nuryami (2021), students' numeracy literacy is still dominated by the procedural level and is weak at the reflection and evaluation stages. These results indicate that many students have difficulty with mathematics problems that are analytical, applied, and problem-based.

Trigonometry is a mathematics topic that demands not only a good conceptual understanding but also the ability to apply these concepts to solve everyday problems, one of which is calculating the height of objects such as buildings, mountains, hills, and trees. Initial observations during classroom learning revealed several difficulties students face with this topic, namely connecting concepts with the problem context, mathematically modeling contextual problems, and representing real contexts in visual form. When working on context-based trigonometry problems, most students immediately look for a relevant formula without analyzing the available information, and they also have difficulty determining an appropriate strategy to solve the problem. This is in line with Ismayanti & Jatisunda (2025), who showed that students' difficulties in trigonometry lie in understanding the relationship between the angles and sides of a triangle and in determining an appropriate strategy to solve trigonometry problems. Similar findings have been reported in international contexts, where secondary school students still make conceptual and procedural errors when solving trigonometry problems, especially problems involving angles of elevation and non-right triangles (Arhin & Hokor, 2021).

Students' problem-solving ability in solving contextual trigonometry problems differs at each stage. Utama et al. (2022) found that the profile of students' mathematical problem-solving ability in trigonometry differs at each of Polya's stages, with students still struggling at the stage of looking back at the solution. Similarly, Tunnajach & Gunawan (2021) reported that students' mathematical problem-solving ability in solving context-based trigonometry problems is still low, especially at the stages of understanding the problem and looking back at the solution. In addition, students tend to apply formulas directly without understanding the problem context, so the solution strategies they use are often inappropriate (Saputra et al., 2020). The characterization of problem solving in contextual mathematical modeling shows that the ability to relate real situations to formal mathematical structures is the stage that most determines successful problem solving, yet it is also the stage students find most difficult to master (Kohen & Nitzan-Tamar, 2022). This is reinforced by the finding that even pre-service mathematics teachers still hold misconceptions when evaluating and constructing mathematical sentences from context-based problems (Ilhan & Akin, 2022).

To date, many studies on mathematical problem-solving ability in trigonometry have focused on gender, learning styles, and routine problems, a tendency also visible in recent qualitative studies of students' mathematical abilities viewed from learning styles and gender (Herawati et al., 2026; Nurhayati et al., 2026). Research in this area has largely emphasized the quantitative measurement of ability or general learning outcomes, whereas qualitative studies that profile students' thinking processes in depth when solving real-context trigonometry problems still need to be strengthened. Real contexts present distinct challenges, such as

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identifying relevant information, constructing mathematical representations of the situation, selecting the appropriate trigonometric concept or ratio, and reinterpreting the results in the original problem context. The novelty of this study lies in mapping in depth the characteristics and stages of students' problem solving on authentic trigonometry problems, rather than merely judging whether the answers are right or wrong. Therefore, this study aims to describe the profile of students' mathematical problem-solving ability in solving real-context trigonometry problems, including their ability to understand the problem, plan a strategy, carry out the solution procedure, and evaluate and reinterpret the results obtained.

## 2. Methodology

This study employed a qualitative research design aimed at revealing in depth the profile of tenth-grade senior high school students' trigonometry problem-solving ability based on Polya's steps across three levels of cognitive ability, namely high, moderate, and low. The research subjects were selected using a snowball sampling technique. The initial procedure was to select the research class, namely class X A, after which one student was chosen as a key informant to point out subjects with a strong tendency toward each of the three ability levels, yielding three initial subjects consisting of one high-ability student, one moderate-ability student, and one low-ability student. Such a qualitative case study approach based on Polya's stages is in line with the research designs used in international contexts to reveal students' thinking processes in solving mathematics problems in depth (Chacón-Castro et al., 2023), as well as with recent qualitative profile studies that categorize subjects in order to describe differences in their mathematical thinking (Nurhidayah et al., 2026; Zahratunnisa et al., 2026).

The problem-solving indicators used in this study were adapted from Pólya (1957) and the National Council of Teachers of Mathematics (2000) and cover four stages. At the stage of understanding the problem, students are expected to identify the information by stating what is known and what is asked, reformulate the problem in their own words, and distinguish relevant from irrelevant information. At the stage of devising a plan, students are expected to choose an appropriate strategy, identify the relationship between the data and the goal, and formulate the solution steps. At the stage of carrying out the plan, students are expected to implement the steps according to the plan, perform calculations accurately, and monitor the progress of the solution. Finally, at the stage of looking back, students are expected to verify the correctness of the answer obtained, reflect on the solution process that has been carried out, and identify possible alternative solutions.

Data were collected using three supporting instruments, namely a student ability classification sheet, a problem-solving ability test sheet, and an interview guideline. The ability classification sheet contained test items on trigonometric ratios, which students completed and which were then scored to group the students by mathematical ability. The problem-solving ability test consisted of two essay items on the subtopic of trigonometric ratios, both set in real-life contexts, namely determining a safe emergency staircase for a school building and analyzing a

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solution for determining the height of a tree using an angle of elevation. Both items required students to understand the context, select an appropriate trigonometric ratio, carry out the calculation, and evaluate the reasonableness of the result, so that all four of Polya's stages could be observed. The test items are presented in Table 1.

Table 1. Problem-Solving Ability Test Items

| Item No. | Item                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.       | <p>A school building will be fitted with an emergency staircase leading to the second floor, which is 6 meters high. The safety standard states that the inclination angle of the staircase must not exceed <math>45^\circ</math>.</p> <ol style="list-style-type: none"> <li>Determine the minimum length of the staircase required to meet the safety standard.</li> <li>If the school only has a staircase 7 meters long, is it safe to use? Explain your reasoning!</li> <li>Provide an alternative solution if the staircase does not meet the safety standard!</li> </ol> |
| 2.       | <p>A student wants to determine the height of a tree using an angle of elevation of <math>45^\circ</math>. The distance from the student to the tree is 10 meters. The student wrote:</p> $\sin 45^\circ = \frac{t}{10}$ <p>so that:</p> $t = 10 \sin 45^\circ$ <ol style="list-style-type: none"> <li>Analyze whether the student's steps are correct or incorrect.</li> <li>If they are incorrect, explain where the error lies.</li> <li>Write the correct solution.</li> <li>Why do errors like this often occur in trigonometry?</li> </ol>                                |

The interview guideline consisted of a list of questions designed to reveal a picture of students' mathematical problem-solving ability, and the interview results were compared with the results of the students' written tests. Both the test and the interviews were conducted face to face. Data validity was established through method triangulation, that is, by comparing the data obtained from the written test with the data obtained from the interview for each subject. The data were analyzed inductively through the following sequence of steps: (1) organizing the data; (2) analyzing the data based on the indicators of each of Polya's stages; (3) stating the research findings; and (4) discussing the research findings in relation to theory and previous studies.

### 3. Results and Discussion

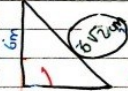
Based on the results of the mathematical ability test, the students selected as research subjects were one student with high mathematical ability (HA), one student with moderate mathematical ability (MA), and one student with low mathematical ability (LA). The following section presents the analysis of the problem-solving test results and the interviews with the three subjects, organized according to Polya's four stages. Across the three subjects, each stage of problem solving was reached with a different degree of completeness, and the looking-back stage was the least developed. This pattern is relevant to international studies showing that context-based mathematical modeling instruction in trigonometry can

improve students' conceptual understanding and problem-solving skills (Ferede et al., 2026; Ferede et al., 2024), which underlines the importance of examining in detail at which stages students still struggle when real contexts are involved.

### ***Problem-Solving Profile of the Student with High Mathematical Ability (HA)***

Based on the analysis of the test answers, subject HA was able to go through the first, second, and third stages of Polya's problem solving well on problem 1. This result is in line with Simamora (2023), who showed that students with high ability were able to fulfill almost all of Polya's problem-solving stages, from understanding the problem to looking back at the answer. At the first step, the subject was able to write down what was known and what was asked in the problem, although incompletely; when interviewed, subject HA admitted to having forgotten to write down the size of the given angle. At the second step, the subject was able to determine the formula that could be used to solve the problem. At the third step, subject HA was not careful in working on problem 1, as seen when  $6 \div (\frac{1}{2}\sqrt{2})$  was rewritten as  $6 \times (\frac{1}{2}\sqrt{2})$ , whereas it should have been  $6 \times (2/\sqrt{2})$ , as shown in Figure 1. Nevertheless, subject HA was able to write the subsequent result correctly, namely  $6 \times (2/\sqrt{2})$ . Subject HA did not go through the fourth step of Polya's problem solving in writing; however, when interviewed, subject HA was able to explain how the chosen formula was checked, as shown in the following interview excerpt: *Researcher: How did you (HA) make sure that the formula you used was correct? HA: I looked at which sides were asked in the problem. In problem 1, what was asked was the length of the staircase, which means the hypotenuse, and what was known was the height of the staircase, 6 m, which is the opposite side. So I used the sine ratio.*

On problem 2, subject HA did not explicitly go through the first and second steps; the subject proceeded directly to solving the problem at the third step. Subject HA was able to write down the correct formula to solve the problem. However, subject HA was not careful in producing the correct answer in part c, assuming that the height of the tree was simply  $t$ , whereas the height of the tree should be  $t$  plus the height of the student. An excerpt of subject HA's written answer to problem 1 is presented in Figure 1.

2.  dik: t. tangga : 6m

a) Panjang tangga agar memenuhi standar

P. tangga :  $\sin 45^\circ = \frac{6}{P}$

$\sin = \frac{1}{2}\sqrt{2} = \frac{6}{P}$   $P = 6 \times \frac{2}{\frac{1}{2}\sqrt{2}} = \frac{12}{\frac{1}{2}\sqrt{2}} = \frac{12 \times 2}{\sqrt{2}} = \frac{24}{\sqrt{2}} = \frac{24 \times \sqrt{2}}{\sqrt{2} \times \sqrt{2}} = \frac{24\sqrt{2}}{2} = 12\sqrt{2}$

Jadi panjang yg memenuhi standar  $12\sqrt{2}$  m

Figure 1. Written work of subject HA on problem 1 (original handwritten answer in Indonesian)



### Problem-Solving Profile of the Student with Low Mathematical Ability (LA)

Based on the analysis of the test answers, subject LA was able to understand the problem given. This can be seen from the answer sheet, in which the subject drew a triangle and wrote down what was known from the problem, although without writing down what was asked. LA then went through the second step by writing down the formula used to solve the problem, which means that the subject was able to use the information to solve the problem. The findings show that the low-ability student had difficulty understanding the problem context and determining a solution strategy. This is in line with Yustinaningrum (2021), who found that students still have difficulty understanding the problem at the initial stage of Polya's problem solving. At the third step, LA was able to solve the problem correctly but did not write the solution steps systematically. At the fourth step, the subject did not write down how to look back at the solution results, as shown in Figure 3.

1.

a.  $\sin 45^\circ = \frac{\text{dikan}}{\text{miring}}$

$\sin 45^\circ = \frac{6}{m}$

$\frac{1}{2}\sqrt{2} = \frac{6}{m}$

$m = \frac{6}{\frac{1}{2}\sqrt{2}} = 6 \cdot \frac{2}{\sqrt{2}} = \frac{12}{\sqrt{2}} = \frac{12\sqrt{2}}{\sqrt{2} \cdot \sqrt{2}} = \frac{12\sqrt{2}}{2} = 6\sqrt{2}$

b. Karena tangga sepanjang 7 meter tidak aman dikarenakan terlalu pendek untuk tinggi gedung

c. solusinya adalah membuat tangga yang lebih panjang.

Figure 3. Written work of subject LA on problem 1 (original handwritten answer in Indonesian)

On problem 2, subject LA was able to write down the information from the problem and draw an illustration of the problem in the form of a triangle. However, the subject could not write down the strategy or formula to be used and therefore could not solve the problem, because, according to the interview, the subject did not fully understand the context of the problem. Oktaviani and Oktaviani & Purwaningsih (2023) likewise showed that low-ability students were only able to fulfill some of the problem-solving indicators and had difficulty determining a strategy for solving trigonometry problems. Similar difficulties in connecting real contexts with formal mathematical models have also been widely reported in international studies, which identify contextual modeling as a major barrier to successful problem solving for low-ability students (Kohen & Nitzan-Tamar, 2022; Utami et al., 2024).

Overall, the differences in problem-solving profiles among the high-, moderate-, and low-ability students in this study are consistent with the four-stage framework of Pólya (1957), namely understanding the problem, devising a plan, carrying out the plan, and looking back. At the stages of understanding the problem and devising

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a plan, the high- and moderate-ability students were relatively able to identify information and determine the appropriate formula, whereas the low-ability student tended to make conceptual errors in linking contextual information with mathematical representations. At the stage of carrying out the plan, all three ability categories showed procedural errors in the form of careless calculations, although the high-ability student recognized and corrected the errors more quickly than the moderate- and low-ability students. The most prominent difference appeared at the looking-back stage, which was the main weakness across all ability categories. This condition is in line with Pólya's (1957) view that looking back requires metacognitive awareness to evaluate the reasonableness of an answer with respect to the problem context, an ability that does not develop automatically from mastery of computational procedures. The weakness at this stage is most likely caused by students' habit of considering a problem finished as soon as the final answer is obtained, without being accustomed to re-verifying either the procedure or the suitability of the answer to the real situation at hand. These findings have important implications for teachers in designing real-context trigonometry instruction that explicitly trains students to reflect on and verify their solutions, for example through guiding questions, modeling of the looking-back step, and the habit of relating computational results to the reasonableness of the real situation they represent. Instructional approaches that actively engage students in solving problems, such as problem-based learning supported by suitable media, have also been shown to improve students' mathematical problem-solving skills (Raihana et al., 2026) and can serve as a vehicle for embedding such reflection routines.

#### **4. Conclusion**

This study succeeded in describing the profile of students' mathematical problem-solving ability in solving real-context trigonometry problems based on Polya's stages, thereby answering the research question. The main profile identified is that the students with high and moderate ability were able to understand the problem, devise a plan, and carry out the solution fairly well, whereas the student with low ability already experienced difficulties at the stages of understanding the problem and devising a strategy. Looking back emerged as the shared weakness across all ability levels, because students tended to regard a problem as finished once a final answer was obtained, without verifying the procedure, the calculation, or the reasonableness of the answer in the real context.

These findings imply that real-context trigonometry instruction should not only emphasize procedural mastery but should also accustom students to reflecting on and verifying their solutions explicitly. Teachers are advised to use guiding questions, model the looking-back step, integrate visual illustrations and real contexts, and provide reinforcement tailored to the characteristic difficulties of each ability level, so that students can connect mathematical solutions with real situations. Because this study involved only a small number of subjects from a single class, future research is recommended to involve more subjects and to examine other factors, such as learning style or self-efficacy, that may influence students' problem-solving profiles.

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