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MATHEMATICAL PROBLEM-SOLVING STRATEGIES OF PRE-SERVICE ELEMENTARY SCHOOL TEACHERS IN SOLVING CONTEXTUAL PROBLEMS

Refni Adesia Pradiarti

Universitas Sunan Gresik, Jl. Dusun Sidorukun, Kec. Sidayu, Kab. Gresik, Jawa Timur, Indonesia
*Corresponding author, email: ra.pradiarti@lecturer.ac.id

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Abstract
This study aims to describe the mathematical problem-solving strategies employed by pre-service elementary school teachers in solving contextual problems based on Polya's problem-solving stages. The study adopted a qualitative approach with a descriptive research design. The participants consisted of 32 students from the Elementary School Teacher Education Program at Sunan Gresik University who completed a mathematical problem-solving test. Three participants were purposively selected to represent high-, moderate-, and low-ability groups. Data were collected through a contextual mathematical problem-solving test, semi-structured interviews, and documentation of the participants' written work. Data were analyzed using the Miles and Huberman model, which includes data reduction, data display, and conclusion drawing. The findings indicate that participants in the high-ability group successfully completed all stages of Polya's problem-solving process systematically, employed appropriate strategies, and accurately interpreted the results within the given context. Participants in the moderate-ability group were able to perform the mathematical procedures correctly but experienced difficulties in reflecting on and interpreting their solutions. Meanwhile, participants in the low-ability group encountered difficulties from the initial stage of understanding the problem, resulting in the use of inappropriate strategies and solutions that did not adequately address the problem requirements. These findings suggest that the ability to understand contextual situations, select appropriate strategies, and reflect on the solution process are key factors distinguishing the mathematical problem-solving performance of pre-service elementary school teachers.

1. Introduction

Twenty-first-century mathematics education positions problem-solving ability as an essential competency that every pre-service elementary school teacher should possess, as it plays a fundamental role in helping students understand, interpret, and solve various problems encountered in everyday life. Strategic competence in solving contextual problems constitutes an important component of the mathematical knowledge for teaching that pre-service teachers are expected to master (Copur-Gencturk & Doleck, 2021). Pre-service teachers' understanding of the nature of mathematical problem solving significantly influences the quality of mathematics instruction they will provide in the classroom (Jiang et al., 2022). However, their pedagogical knowledge related to problem solving still requires further development to effectively facilitate student-centered learning (Piñeiro et al., 2021). Faizah et al. (2026) reported that the mathematical problem-solving ability of pre-service elementary school teachers remains a critical issue in teacher education and warrants further empirical investigation. Likewise, pre-service teachers' understanding of mathematical problems and their instructional approaches influences their readiness to foster students' mathematical thinking (Giyarti et al., 2025).

Contextual problems have been widely recommended as a form of mathematical task because they effectively connect mathematical concepts with authentic situations that are relevant to students' everyday experiences. Hansen (2022) found that pre-service teachers tend to select reallife contexts when designing mathematical modeling tasks because such contexts are considered more meaningful for elementary school students. Similarly, Kohar et al. (2022) demonstrated that the ability to relate mathematical concepts to real-world contexts is an important component of future teachers' professional competence. Nevertheless, many pre-service teachers still experience difficulties in transforming real-world situations into mathematical problems that satisfy the characteristics of mathematical modeling. Engaging in the design of context-based mathematical tasks can enhance pre-service teachers' conceptual understanding of mathematics (Paolucci & Stepp, 2021). Therefore, the ability to integrate and connect mathematical concepts is a crucial factor in successfully solving contextual problems.

Pre-service elementary school teachers play a strategic role because they are expected not only to solve mathematical problems but also to understand and explain the strategies they employ so that these strategies can subsequently be taught to their future students. However, analyzing students' mathematical solutions remains a challenge for many pre-service elementary school teachers (Burgos & Godino, 2022). Pöysä-Tarhonen et al. (2022) found that collaborative problem-solving activities help pre-service teachers develop stronger conceptual understanding and reflective thinking. Furthermore, learning experiences involving problem solving can enhance students' confidence in dealing with complex mathematical tasks (Schanke, 2023). Mutaqin et al. (2025) reported considerable variation among pre-service elementary school teachers in their ability to understand problems, model mathematical situations, execute solution procedures, and formulate conclusions. These findings suggest that the strategies employed by pre-service teachers in solving contextual mathematical problems deserve further investigation to provide a clearer understanding of their professional competence.

Previous studies consistently indicate that successful mathematical problem solving depends not only on conceptual knowledge but also on the strategies employed throughout the problem-solving process. Flexible problem-solving strategies enable students to explore multiple solution pathways when confronted with non-routine problems (Foster et al., 2022). Appropriate strategy selection facilitates the integration of contextual information with mathematical concepts, thereby supporting more effective problem solving. The problem-solving process generally consists of understanding the problem, planning a solution, implementing the plan, and evaluating the obtained solution (Pradiarti & Subanji, 2022). Despite understanding the information presented in a problem, pre-service elementary school teachers frequently encounter difficulties in selecting appropriate solution strategies. This issue highlights the importance of identifying the strategies they employ when solving contextual mathematical problems.

The characteristics of contextual problems, which require the interpretation of authentic situations, often lead students to adopt diverse solution strategies. Compared with routine procedural tasks, contextual problems encourage more sophisticated mathematical reasoning and are closely associated with mathematical modeling competence. Lalihatu et al. (2026) found that many university students experience difficulties in transforming verbal representations into formal mathematical expressions when solving context-based problems. Moreover, Resi and Nay (2026) reported that variations in contextual problem-solving strategies are influenced by students' learning experiences and their ability to represent mathematical information. Consequently, examining students' problem-solving strategies provides deeper insights into their mathematical thinking than merely evaluating their final answers.

Although research on mathematical problem solving has grown substantially, most studies have focused on elementary school students, secondary school students, or undergraduate students majoring in mathematics education. Research involving pre-service elementary school teachers remains relatively limited, particularly studies examining the strategies they employ while solving contextual mathematical problems. Existing systematic reviews indicate that most previous research has primarily emphasized measuring problem-solving ability rather than investigating the cognitive processes and strategies underlying successful problem solving. Other studies have predominantly explored critical thinking, creativity, or mathematical literacy without providing detailed explanations of how students construct problem-solving strategies. These limitations reveal a significant research gap that can be addressed through investigations focusing specifically on the problem-solving strategies employed by pre-service elementary school teachers when solving contextual mathematical problems. Understanding these strategies is essential for developing teacher education programs that are more effective and aligned with the demands of twenty-first-century mathematics education.

Based on the foregoing discussion, investigating the mathematical problem-solving strategies of pre-service elementary school teachers in solving contextual mathematical problems is both timely and necessary. This study seeks to provide a comprehensive description of how pre-service teachers understand problems, formulate solution plans, implement problem-solving strategies, and reflect upon their solutions. The findings are expected to assist teacher educators in designing instructional approaches that better promote mathematical problem-solving ability and mathematical reasoning among pre-service teachers. Furthermore, this study contributes to the relatively limited body of literature on mathematics education within elementary teacher education programs. Accordingly, the purpose of this study is to describe and explore the mathematical problem-solving strategies employed by pre-service elementary school teachers in solving contextual mathematical problems.

2. Method

This study employed a qualitative approach with a descriptive research design to explore and comprehensively describe the mathematical problem-solving strategies of pre-service elementary school teachers in solving contextual problems. A qualitative approach was selected because the study focused on the participants' thinking processes and problem-solving strategies rather than on the quantitative measurement of learning outcomes. The study was conducted with students enrolled in the Elementary School Teacher Education (PGSD) Program at Sunan Gresik University who were taking the Basic Mathematics course during the second semester of the 2025/2026 academic year. The initial participants consisted of 32 students from Class C25, who completed a contextual mathematical problem-solving test based on everyday-life situations. The test was designed to identify the strategies employed by the participants at each stage of the problem-solving process, thereby enabling the researchers to obtain a comprehensive understanding of how the problems were solved.

The data collection process began with the administration of the contextual mathematical problem-solving test to all 32 participants. The test results were then ranked according to the participants' scores. Subsequently, the research participants were selected purposively based on their test performance, communication skills, and willingness to participate in in-depth interviews. The participant selection procedure followed the common practice in qualitative mathematics education research, in which one participant from each ability level (high, moderate, and low) is selected to obtain an in-depth understanding of the characteristics of mathematical problem-solving. Accordingly, three participants representing the high-, moderate-, and low-ability groups were selected, as presented in Table 1.

Table 1. Criteria for Participant Selection

Ability Category	Selection Criteria
High	Participant who obtained the highest score and represented the high-ability group.
Moderate	Participant whose score was close to the class average and represented the moderate-ability group.
Low	Participant who obtained the lowest score and represented the low-ability group.

Source: Adapted from Juniarti et al. (2022).

Research data were collected through a contextual mathematical problem-solving test, semi-structured interviews, and documentation of the participants' written work. The interviews were conducted after the participants completed the test to explore the reasoning, considerations, and thought processes underlying each step of their problem-solving procedures.

Data were analyzed using the model proposed by Miles et al. (2014), which consists of data reduction, data display, and conclusion drawing. The analysis of problem-solving strategies was based on Polya's problem-solving stages, namely understanding the problem, devising a plan, carrying out the plan, and looking back.

The trustworthiness of the data was ensured through method triangulation by comparing evidence obtained from the problem-solving test, interview transcripts, and documentation of the participants' written work. The results of the analysis were then used to describe the characteristics of the mathematical problem-solving strategies employed by high-, moderate-, and low-ability pre-service elementary school teachers when solving contextual mathematical problems.

3. Result and Discusion

3.1. Result

The findings of this study focus on describing the mathematical problem-solving strategies employed by pre-service elementary school teachers in solving contextual mathematical problems. The analysis was based on the results of the mathematical problem-solving test and in-depth interviews with three participants representing the **high-ability (S1), moderate-ability (S2), and low-ability (S3)** groups. The participants were categorized according to the results of a problem-solving test administered to **33 students** enrolled in the Elementary School Teacher Education (PGSD) Program, Class D25, at Sunan Gresik University. Participant selection was based on test scores, communication skills, and willingness to participate in the interviews, resulting in one participant being selected from each ability group.

The contextual problem used in this study concerned the relationship between students' study time and examination scores, modeled using a quadratic function. The problem was designed to identify the participants' ability to understand contextual information, relate it to the concept of a quadratic function, select appropriate solution strategies, and interpret the results within the given context. The mathematical model used in the problem is presented in **Equation (1)**.

$$f(x) = -2x^2 + 26x + 40 \qquad (1)$$

where $x$represents the student's study time (hours), and $f(x)$ denotes the examination score obtained by the student. Based on this model, the participants were asked to determine the examination score of a student who studied for **2 hours** and to determine the maximum value of $x$that would allow the student to achieve the maximum possible examination score of **100**, according to the given function.

This problem was selected because it integrates several interrelated mathematical concepts, including substitution into a function, understanding the characteristics of quadratic functions, determining the vertex of a parabola, and interpreting mathematical results within a real-world context. Furthermore, the problem allows different problem-solving strategies to emerge across the three ability groups, thereby providing deeper insights into the participants' mathematical thinking processes during problem solving.

The analysis of the problem-solving strategies was conducted based on **Polya's problem-solving stages**, namely **understanding the problem, devising a plan, carrying out the plan, and looking back**. Data were obtained through analyses of the participants' written work and semi-structured interviews, enabling each step of the problem-solving process to be examined comprehensively. The results of the analysis for each participant are presented in the following sections.

Problem-Solving Strategies of High-Ability Students (S1)

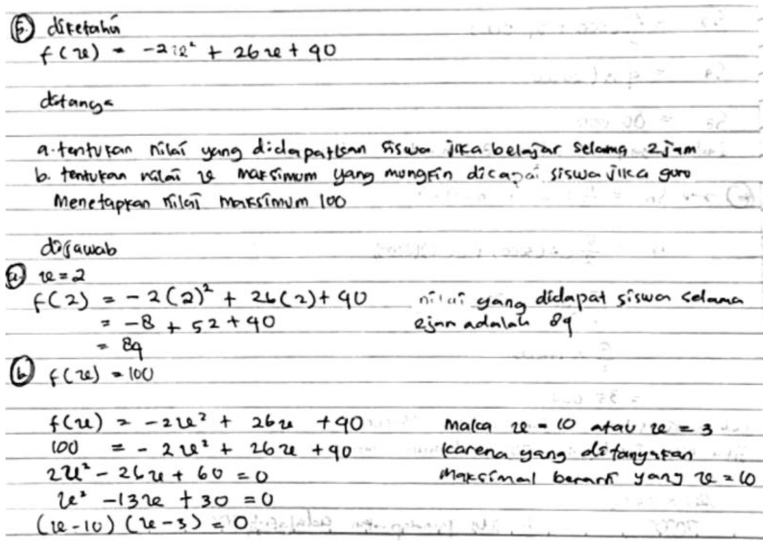

Figure 1. Problem-Solving Results by S1

S1 represents a participant in the high-ability category. Based on the written work and interview data, S1 demonstrated systematic problem-solving ability across all stages of Polya's framework.

In the **understanding the problem** stage, S1 was able to correctly identify all given and required information. S1 understood that the function

$$f(x) = -2x^2 + 26x + 40$$

represents the relationship between students' study time and their obtained test scores. S1 also recognized that the problem consists of two tasks: determining the test score when the student studies for 2 hours, and determining the maximum value of x that corresponds to a maximum score of 100. This understanding indicates that S1 was able to distinguish between the function value and the variable requested in the problem.

S1's ability to understand the problem was also evident in how contextual information was connected to the mathematical model. From the interview data, S1 explained that the value 100 in the problem is not an unknown to be solved but a predetermined maximum score set by the teacher. Therefore, S1 identified that the appropriate step was to determine the study duration that yields a score of 100. This shows that S1 was able to accurately interpret contextual information before performing calculations.

In the **devising a plan** stage, S1 applied different strategies for each question. For the first question, S1 used direct substitution by replacing $x = 2$ into the function. For the second question, S1 constructed a mathematical equation by setting the function value equal to 100, resulting in:

$$-2x^2 + 26x + 40 = 100$$

S1 then planned to use the factorization method to solve the resulting quadratic equation. This strategy selection indicates that S1 understood the relationship between the contextual problem and quadratic equation concepts.

In the **carrying out the plan** stage, S1 correctly substituted $x = 2$ into the function, obtaining:

$$f(2) = -2(2)^2 + 26(2) + 40 = 84$$

Thus, S1 concluded that a student studying for 2 hours would obtain a score of 84.

For the second part, S1 transformed the equation into:

$$-2x^2 + 26x - 60 = 0$$

and simplified it to:

$$x^2 - 13x + 30 = 0$$

Through factorization, S1 obtained:

$$(x - 3)(x - 10) = 0$$

resulting in two possible solutions, $x = 3$ and $x = 10$. S1 then concluded that the maximum study time yielding a score of 100 is 10 hours. All calculations were performed systematically without conceptual or procedural errors.

In the final stage, **looking back**, S1 verified the results by substituting $x = 3$ and $x = 10$ back into the function to ensure that both values produce a score of 100. After confirming the correctness of the solutions, S1 concluded that, since the problem asks for the maximum value of x, the appropriate answer is $x = 10$. These findings indicate that S1 not only performed mathematical procedures correctly but also interpreted the meaning of the solution in accordance with the problem context. Overall, S1's strategy reflects a systematic, conceptual, reflective, and contextual problem solver.

Problem-Solving Strategies of Moderate-Ability Participants (S2)

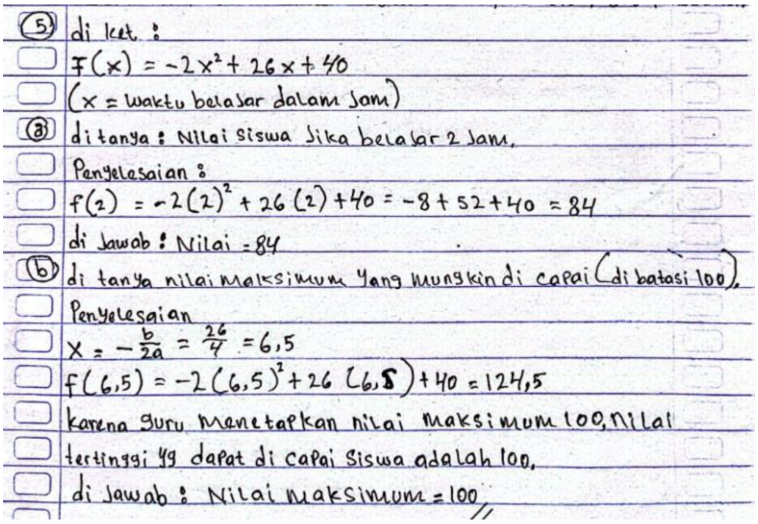

Figure 2. Problem-Solving Results by S2

S2 represents a participant in the moderate-ability category. Based on the written work and interview data, S2 was able to complete most stages of the problem-solving process; however, errors were identified in interpreting the information provided in the problem.

In the **understanding the problem** stage, S2 was able to identify the given function and recognized that the first question required evaluating the function at $x = 2$. S2 also understood that the second question was related to a maximum value. However, S2's interpretation of the statement "the teacher sets the maximum score as 100" was not fully accurate.

In the **devising a plan** stage, S2 selected a direct substitution strategy for the first question, as the value of x was explicitly given. For the second question, S2 associated the term "maximum" with the vertex of a quadratic function. Based on the interview results, S2 stated that when encountering the term maximum value in a quadratic function, the first procedure that came to mind was applying the vertex formula $-b/2a$. This indicates that S2 tended to rely more on previously learned procedures rather than fully interpreting the contextual meaning of the problem.

In the **carrying out the plan** stage, S2 correctly substituted $x = 2$ into the function and obtained:

$$f(2) = 84$$

For the second part, S2 applied the vertex formula of a quadratic function:

$$x = \frac{-b}{2a}$$

resulting in:

$$x = \frac{-26}{2(-2)} = 6.5$$

This value was recorded as the final answer. Mathematically, the procedure used by S2 is correct for determining the vertex (axis of symmetry) of a parabola. However, this strategy does not align with the problem requirement, which asks for the value of x when the test score reaches 100.

In the **looking back** stage, S2 only checked the computational procedure without re-examining the contextual meaning of the problem. S2 did not realize that the actual problem required solving the equation

$$-2x^2 + 26x + 40 = 100$$

to determine the study time that produces a score of 100. After being prompted during the interview, S2 realized that the value 100 should be treated as a known function value. These findings indicate that S2's reflective and interpretative abilities were not yet optimal. The strategy employed by S2 was predominantly procedural, focusing on the application of familiar formulas without first critically analyzing the contextual meaning of the given information.

Problem-Solving Strategies of Low-Ability Participants (S3)

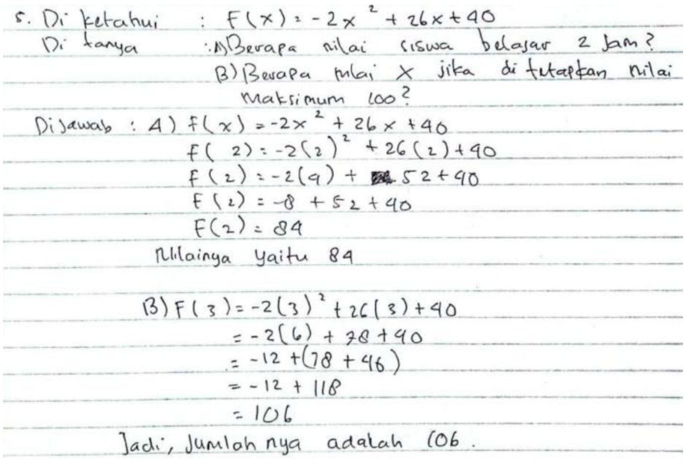

Figure 3. Problem-Solving Results by S3

S3 represents a participant in the low-ability category. Based on the written work and interview data, S3 experienced difficulties across nearly all stages of the problem-solving process. These difficulties were evident from the understanding phase and continued through the solution process, resulting in answers that did not meet the problem requirements.

In the **understanding the problem** stage, S3 was only able to identify that the problem involved students' study time and examination scores. S3 recognized that a quadratic function was involved, but did not understand the relationship between the function value and the variable being asked. Interview data indicated that S3 did not understand that the second question required determining the value of $x$that produces a score of 100. As a result, important information in the problem was not appropriately utilized during the solution process.

The difficulty in understanding the problem also affected the **devising a plan** stage. S3 was unable to determine an appropriate strategy for solving the second question. In contrast to S1, who modeled the equation $f(x) = 100$, S3 directly selected one of the values obtained during the solution process without a clear mathematical justification. This indicates that S3 was not able to connect the contextual problem with relevant quadratic equation concepts.

In the **carrying out the plan** stage, S3 was still able to substitute $x = 2$ into the function, although some computational errors occurred and were later corrected. For the second part, S3 directly substituted $x = 3$ into the function without first determining the value of x that satisfies the condition $f(x) = 100$. S3 assumed that the value 3 was the final answer, thereby stopping the solution process at that point, even though the obtained result was 106. This step indicates that S3 did not understand the procedure required to determine the maximum value of x as requested in the problem.

The **looking back** stage was almost absent in S3's solution process. After obtaining a numerical result, S3 immediately wrote the final answer without verifying whether the steps taken actually addressed the problem. During the interview, S3 admitted not knowing how to determine the maximum study time that yields a score of 100. These findings indicate that S3's problem-solving strategy did not fully follow Polya's stages. The solution process was dominated by unstructured procedural attempts and was not supported by sufficient conceptual understanding. As a result, the final solution did not correspond to the requirements of the contextual problem.

3.2. Discussion

The results of this study show that high-ability pre-service elementary school teachers are able to carry out all stages of the problem-solving process systematically, starting from understanding the problem, planning a solution, implementing the strategy, and finally reviewing the obtained results. These findings are consistent with the problem-solving process model proposed by Rotte et al. (2021), which explains that successful problem solvers tend to perform structured transitions between phases and evaluate the solutions they generate. The performance of S1 is evident in the ability to recognize that the first question can be solved through substitution of $x = 2$ into the function, while the second question requires reformulating the problem into the quadratic equation $f(x) = 100$. This finding aligns with Piñeiro et al. (2021), who state that pre-service teachers with strong conceptual understanding tend to select more effective strategies when dealing with non-routine problems. S1's ability to transform the quadratic function into a quadratic equation, determine its roots, and interpret the meaning of the solutions indicates that their understanding is not merely procedural but also conceptual in nature. Furthermore, S1's reflective ability in the "looking back" stage allowed verification that $x = 3$ and $x = 10$ both satisfy the condition $f(x) = 100$, before selecting $x = 10$ as the final answer in accordance with the contextual requirement.

The results also indicate that moderate-ability participants are able to correctly execute routine mathematical procedures but still experience difficulties in interpreting contextual information within the problem. This is evident in S2's case, where the participant successfully calculated the function value for $x = 2$ but directly applied the vertex formula $-b/2a$ for the second question due to associating the term "maximum" with the characteristics of quadratic functions. This finding suggests that successful application of mathematical procedures does not necessarily correspond to an accurate understanding of the mathematical meaning embedded in the problem context. Problem-solving performance based on Polya's stages shows that many learners are able to implement solution plans but still struggle in the "looking back" stage and in interpreting the obtained results (Pradiarti & Subanji, 2022). Similar findings were reported by Sari et al. (2025), who found that pre-service teachers often apply formulas perceived as most relevant without first analyzing key information in the problem. These findings indicate that problem interpretation skills need to be strengthened so that students can distinguish between situations requiring vertex application and those requiring equation-solving approaches.

Low-ability participants show difficulties from the initial stage of understanding the problem, which subsequently affects the appropriateness of strategies used in later stages. Difficulties in understanding the relationship between function values and variables prevent S3 from recognizing that the second question requires constructing the equation $f(x) = 100$. This finding reinforces the view that problem understanding is a fundamental foundation in mathematical problem solving. Failure at this stage often leads to a chain of errors in both planning and execution (Madzkiyah & Arifin, 2024). The results show that S3 directly substituted $x = 3$ into the function without identifying its origin or determining the correct value of $x$that satisfies the condition in the problem. This is consistent with findings by Sari et al. (2025), which show that low-ability students generally experience difficulties in selecting strategies and connecting mathematical concepts with problem requirements. These difficulties indicate the need for instruction that not only emphasizes procedural fluency but also strengthens students' ability to model real-world problems into appropriate mathematical forms.

The differences in strategies among the three participants demonstrate that the quality of problem solving is strongly influenced by the ability to select and manage strategies throughout the solution process. S1 employed a flexible strategy by simultaneously connecting quadratic functions, quadratic equations, and contextual interpretation, leading to accurate solutions. S2 focused more on previously learned procedures, resulting in a failure to recognize that 100 represents a known function value rather than a value to be determined using the vertex. S3 was unable to establish relationships between known information and relevant concepts, resulting in an unstructured and ineffective problem-solving approach. Segura and Ferrando (2023) found that high-ability individuals tend to use multiple representations and more adaptive strategies compared to low-ability individuals. Learning experiences involving investigative and problem-solving activities also contribute to the development of appropriate strategy selection skills in relation to problem characteristics. These findings indicate that developing problem-solving ability cannot rely solely on procedural exercises, but must also involve activities that encourage students to explore relationships between functions, equations, and contextual situations (Pradiarti et al., 2024; Weber et al., 2025).

The findings of this study have important implications for elementary teacher education. The ability to model contextual problems into mathematical representations is a key factor distinguishing performance across ability levels. Students who are able to understand the relationship between quadratic functions and quadratic equations tend to develop more appropriate strategies compared to those who rely solely on mechanical application of formulas. Pre-service teachers' knowledge of problem-solving processes and strategies is an essential component of their professional competence that must be developed during their studies. Mathematics instruction in teacher education programs should be designed to provide opportunities for students to solve contextual problems that require representation, mathematical modeling, reflection, and interpretation. This study also reinforces the importance of Polya's stages as a framework for developing problem-solving skills, as each stage contributes differently to students' ability to understand, model, solve, and evaluate solutions.

4. Conclusion

This study aimed to describe the mathematical problem-solving strategies of pre-service elementary school teachers in solving contextual problems based on Polya's stages. The findings reveal differences in the characteristics of problem-solving strategies among students with high, medium, and low abilities. High-ability students (S1) were able to carry out all stages of problem solving systematically, including understanding the problem, devising a plan, carrying out the strategy, and looking back at the obtained results. S1 not only performed calculations correctly but also interpreted the results in accordance with the problem context, resulting in solutions that were both accurate and meaningful. Medium-ability students (S2) demonstrated good performance in understanding the problem and executing mathematical procedures; however, they still experienced difficulties in the reflection and interpretation stages. Meanwhile, low-ability students (S3) encountered difficulties from the initial stage of understanding the problem, which subsequently affected the appropriateness of their strategies in subsequent stages and led to solutions that did not align with the problem requirements.

The findings indicate that the quality of mathematical problem solving is not solely determined by computational skills, but also by the ability to understand context, select appropriate strategies, and reflect on the obtained solutions. Reflective and interpretative abilities emerge as the main distinguishing factors among students with high, medium, and low abilities. Therefore, mathematics instruction in elementary teacher education programs should be designed to provide contextual problem-solving experiences that emphasize conceptual understanding, mathematical reasoning, and reflective thinking. This study contributes to the enrichment of research on mathematical problem-solving strategies among pre-service elementary school teachers and provides a characterization of problem-solving strategies across ability levels. These findings can serve as a foundation for developing instructional practices and further research on mathematical problem solving in elementary teacher education.

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