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Pre-Service Teachers' Level and Processes of Metacognition in Non-Routine Problem Solving

Mary Joy T. Alicaway[1]*, Amelia T. Buan[1], Generie Mae G. San Pablo[1], Mary Joy F. Luga[2], Hassan S. Gandamra[1]

[1]Department of Science and Mathematics Education, College of Education, Mindanao State University - Iligan Institute of Technology, Philippines

[2]MSU – IIT College of Education - Integrated Developmental School

[*]Corresponding Author

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ABSTRACT

Metacognition is essential in mathematical problem-solving because it enables learners to plan, monitor, and evaluate their thinking while solving unfamiliar tasks. This study aimed to determine the level of metacognition of pre-service mathematics teachers and describe their metacognitive processes in terms of planning, monitoring, and evaluation while solving non-routine mathematical problems. A descriptive research design supported by qualitative data was employed. The participants were 27 third-year secondary mathematics pre-service teachers from the College of Education, Mindanao State University–Iligan Institute of Technology, selected through purposive sampling. Data were gathered using two non-routine mathematical problems, written solutions, reflective journals, and a validated metacognition scoring rubric. Quantitative data were analyzed using mean, standard deviation, frequency, and percentage, while qualitative data were analyzed deductively based on planning, monitoring, and evaluation. Results revealed that the pre-service teachers demonstrated a moderate level of metacognition ($M = 6.15$). Planning, monitoring, and evaluation were evident in their solutions; however, evaluation emerged as the least consistently demonstrated metacognitive process. Qualitative findings showed that high-level pre-service teachers demonstrated systematic planning, active monitoring, and careful evaluation, whereas moderate- and low-level pre-service teachers showed partial or developing metacognition, misunderstanding of problem conditions, and limited verification of answers. The findings suggest the need to strengthen metacognitive instruction to better prepare future mathematics teachers for reflective and effective problem-solving.

Keywords: Pre-Service Teachers, Metacognition, Non-Routine Problem-Solving

INTRODUCTION

Teachers contribute significantly to the development of learners (DepEd, 2017). In a mathematics classroom, teachers are not only expected to deliver content but also to help students understand mathematical ideas, reason through problems, and make sense of unfamiliar situations. This role aligns with the vision of the National Council of Teachers of Mathematics, which has long advocated problem-solving as a primary means of learning mathematics (Wilkerson, 2022). It aims to develop problem-solvers who become productive citizens, use mathematics confidently and meaningfully in daily life, and view mathematics as a sense-making process through conjectures and justifications of results (NCTM, 2000; Wilkerson, 2022). Similarly, the K–12 mathematics curriculum emphasizes problem-solving and critical thinking as twin goals of mathematics education.

However, studies show that pre-service teachers frequently rely on limited problem-solving strategies, have limited authentic mathematical experiences, and encounter difficulties in solving non-routine mathematical problems (Ajani, 2024; Akyüz, 2020; Usta, 2020). Jiang et al. (2022) also stressed the importance of strengthening creativity, initiative, and student-centered problem-solving instruction among pre-service teachers. These concerns emphasized the need to strengthen mathematics teacher preparation, particularly among pre-service teachers who will eventually teach problem-solving in K–12 classrooms. They are expected not only to solve mathematical problems correctly but also to model effective reasoning, strategic thinking, and reflective problem-solving for their future learners. Their ability to solve non-routine problems is important because they will later be responsible for helping students understand unfamiliar mathematical situations.

Metacognition, commonly described as 'thinking about thinking,' enables learners to plan, monitor, regulate, and evaluate their thinking processes during problem-solving (Darr & Fisher, 2005; Vadivu et al., 2025). Desoete (2007) emphasized that metacognitive strategies can improve mathematical reasoning and problem-solving performance. Among pre-service teachers, metacognitive skills are important because they support their own mathematical understanding and prepare them to guide future learners in reflective and strategic problem-solving (Fono & Zohar, 2024). Therefore, this study aimed to describe the level and processes of metacognition of pre-service mathematics teachers while solving non-routine mathematical problems. The findings are expected to provide insights for improving teacher preparation, informing teaching strategies, and supporting curriculum development for meaningful mathematical problem-solving in future K-12 classrooms.

METHODOLOGY

Research Design and Participants

The primary objective of this study was to determine the level of metacognition of pre-service mathematics teachers and describe their metacognitive processes in terms of planning, monitoring, and evaluation while solving non-routine mathematical problems. To address this objective, the study employed a descriptive research design supported by qualitative data, as it aimed to describe the existing characteristics, behaviors, levels, and processes of pre-service teachers as they naturally occurred (Fraenkel et al., 2012).

The participants were 27 third-year secondary mathematics pre-service teachers from the College of Education, Mindanao State University-Iligan Institute of Technology. They were purposively selected because they are future K-12 mathematics teachers who are expected to facilitate mathematical problem-solving in classroom settings. As third-year pre-service mathematics teachers, the participants had prior exposure to foundational and intermediate mathematics courses, making them suitable for tasks involving non-routine mathematical problem-solving. The study was conducted in one institution; hence, the findings are context-specific and are not intended for broad generalization to all pre-service teacher populations.

Prior to data collection, the researchers obtained the necessary ethical and administrative clearances. Ethical approval was sought from the Research Integrity and Compliance Office (RICO). After the certificate was issued, it was attached to the formal request letter submitted to the Dean's Office of the College of Education, MSU-Iligan Institute of Technology. A letter was also forwarded to the course instructor to facilitate the participation of the selected pre-service teachers. Participation was voluntary, and informed consent was obtained from all third-year pre-service teachers.

Research Instruments

The study used two non-routine mathematical problems, written solutions, reflective journals, and a metacognition scoring rubric. The two problems were adapted and modified to fit the objective of the study. Also, they were selected because they required unfamiliar, non-algorithmic reasoning and were expected to elicit planning, monitoring, and evaluation. Problem 1 (adapted from non-routine problems available through Scribd), referred to as Sally's Partner, required the pre-service teachers to determine Sally's partner number under the condition that the sum of each pair of numbers was a perfect square. Problem 2 (adapted from the OECD, 2006 PISA released mathematics items), referred to as Conifer and Apple Trees, required the pre-service teachers to compare the growth of apple trees and conifer trees in a square-pattern orchard.

The written solutions served as the main source for scoring the pre-service teachers' level of metacognition. The reflective journals provided qualitative support by capturing their explanations of what they understood, what strategies they planned to use, whether they encountered difficulty, how they checked their work, and whether they believed their final answer was correct. The journal prompts were designed to elicit evidence of planning, monitoring, and evaluation during the problem-solving process.

Validation and Reliability of Instruments

The non-routine problems, scoring rubric for metacognition, and reflective journal prompts were subjected to expert validation before data collection. Two mathematics education experts evaluated the instruments in terms of alignment with the research objective, clarity, usability, integration of metacognition, appropriateness for pre-service teachers, and suitability for eliciting planning, monitoring, and evaluation. The validation checklist used yes/no responses, where a 'yes' response indicated that the criterion met the expected standard and a 'no' response indicated that revision was needed. Validators also provided comments and suggestions for improving the instruments.

Table 1 below presents the validation results of the three research instruments.

Table 1. Validation Result of Research Instruments

Tool	Total Yes Responses	Total Criteria	Overall Percentage
Non-routine Problems for Metacognition	8	8	100%
Scoring Rubric for Metacognition	4	8	50%

Reflection Journal	5	6	83.33%
Overall	**17**	**22**	**77.78%**

The validation result showed an overall percentage of 77.78%, interpreted as valid with minor revisions. This means that the instruments were valid for use after revisions were made to improve clarity, alignment, and appropriateness. The validators' comments and suggestions were considered before the instruments were administered.

To establish scoring reliability, the instruments were pilot tested with three second-year pre-service mathematics teachers. Three raters, including the researcher, independently scored the pre-service teachers' written outputs using the validated rubric. Before scoring, the raters were oriented on the rubric criteria, score levels, and scoring procedures to ensure a common understanding of the indicators. The consistency of the raters' scores was examined using the Intraclass Correlation Coefficient (ICC), which is appropriate for numerical ratings involving more than two raters (Hallgren, 2012; Koo & Li, 2016). The metacognition scoring rubric obtained an ICC of 0.9622, indicating excellent reliability.

Scoring and Interpretation

The pre-service teachers' written solutions were scored using a 10-point metacognition rubric based on three processes: planning, monitoring, and evaluation. *Planning* referred to evidence of understanding the problem, identifying relevant information, setting goals, and selecting strategies. *Monitoring* referred to evidence of checking progress, detecting errors, revising strategies, and determining whether the solution process was working. *Evaluation* referred to evidence of verifying the final answer, checking whether all conditions were satisfied, and judging the reasonableness of the solution.

Table 2 below presents the interpretation scale of metacognitive scores. The interpretation scale was developed by the researcher based on the total possible score of the metacognition rubric and was divided into performance levels to describe the extent to which the pre-service teachers demonstrated metacognitive processes.

Table 2. Interpretation of Metacognition Scores

Score Mean Range	Interpretation	Description
9.00-10.00	High	Complete evidence of planning, monitoring, and evaluation
5.00-8.99	Moderate	Partial or developing evidence of planning, monitoring, and evaluation
0.00-4.99	Low	Limited or unclear evidence of planning, monitoring, and evaluation

The score ranges for metacognition were based on the 10-point rubric. Scores from 9.00 to 10.00 indicated complete or nearly complete evidence of planning, monitoring, and evaluation; scores from 5.00 to 8.99 indicated partial or developing evidence of these processes; and scores from 0.00 to 4.99 indicated limited or unclear evidence of planning, monitoring, and evaluation. The interpretation scale was reviewed during validation to ensure its appropriateness for classifying pre-service teachers' metacognitive performance.

Data Analysis and Trustworthiness

Quantitative data were analyzed using mean, standard deviation, frequency, and percentage to determine the pre-service teachers' level of metacognition. Qualitative data from written solutions and reflective journals were analyzed deductively according to the metacognitive processes of planning, monitoring, and evaluation. Representative pre-service teachers from high, moderate, and low metacognition levels were selected to support and clarify the quantitative findings. Trustworthiness was established through cross-checking their written solutions and reflective journals, participant coding for confidentiality, inclusion of direct statements from reflective journals, and inter-rater reliability to ensure scoring consistency. All qualitative interpretations were aligned with the rubric indicators, and each pre-service teacher was assigned a unique code (e.g., P1) for systematic identification and consistency of reporting the results.

RESULTS AND DISCUSSION

Pre-service Teachers' Level of Metacognition

Table 3 below presents the mean and standard deviation of the pre-service teachers' metacognition scores in the two non-routine problems.

Table 3. Mean and Standard Deviation of Pre-service Teachers' Metacognition Scores

Non-routine Problem	N	Mean	SD	Interpretation
Problem 1: Sally's Partner	27	5.70	3.64	Moderate

Problem 2: Conifer and Apple Trees	27	6.59	2.42	Moderate
Overall	**27**	**6.15**	**3.03**	**Moderate**

Note: Non-routine Problem for Metacognition is 10 points – Planning (3 points), Monitoring (4 points), Evaluation (3 points)

Both problems 1 and 2 were interpreted as moderate levels with M = 5.70, SD = 3.64, and M = 6.59, SD = 2.42, respectively. The overall M = 6.15 also indicated a moderate level of metacognition. This result suggested that the secondary mathematics pre-service teachers generally demonstrated partial or developing performance in planning, monitoring, and evaluation while solving non-routine problems. The moderate result indicated that the pre-service teachers were able to demonstrate metacognitive processes, but these were not consistently evident across all solutions. Although Problem 2 obtained a higher mean score than Problem 1, still both remained within the moderate level. The higher standard deviation in Problem 1 suggested greater variation in the secondary mathematics pre-service teachers' metacognition scores, while the lower standard deviation in Problem 2 indicated relatively more consistent performance. This implies that their planning, monitoring, and evaluation were more varied in Problem 1 than in Problem 2.

Table 4 below presents the frequency and percentage distribution of pre-service teachers according to their level of metacognition in the two non-routine problems and their overall metacognition level.

Table 4. Frequency and Percentage Distribution of Pre-service Teachers' Level of Metacognition

Level of Metacognition	**Problem 1**		**Problem 2**		**Overall**	
	f	***%***	***f***	***%***	***f***	***%***
High	10	37.04	8	29.63	9	33.33
Moderate	6	22.22	14	51.85	10	37.04
Low	11	40.74	5	18.52	8	29.63
Total	**27**	**100**	**27**	**100**	**27**	**100**

Note: High (9.00-10.00), Moderate (5.00-8.99), Low (0.00-4.99)

In Problem 1, the largest group of pre-service teachers were classified as the low level (n = 11, 40.74%), followed by the high level (n = 10, 37.04%) and the moderate level (n = 6, 22.22%). In Problem 2, the largest group was classified as the moderate level (n = 14, 51.85%), followed by the high level (n = 8, 29.63%) and the low level (n = 5, 18.52%). In sum, the largest group of pre-service teachers were classified as the moderate level (n = 10, 37.04%), followed by the high level (n = 9, 33.33%) and the low level (n = 8, 29.63%).

The distribution indicated that the metacognition of secondary mathematics pre-service teachers varied across the two non-routine problems. A greater proportion of pre-service teachers fell at the low level in Problem 1 than in Problem 2, whereas a greater proportion fell at the moderate level in Problem 2. This suggested that Problem 1 posed greater challenges in terms of planning, monitoring, and evaluation. The nature of the task may have required more systematic reasoning and verification, which some pre-service teachers found difficult to sustain throughout the solution process. In contrast, Problem 2 appeared to be more accessible, allowing more pre-service teachers to demonstrate moderate metacognitive performance. However, the overall distribution, with the largest group classified at the moderate level, reinforces the moderate metacognition score obtained by the pre-service teachers.

Table 5 below presents the mean scores of pre-service teachers' metacognitive processes in solving non-routine problems.

Table 5. Mean Scores of Pre-service Teachers' Metacognitive Processes in Solving Non-routine Problems

Metacognitive Processes	*Planning*	*Monitoring*	*Evaluation*	**Overall Mean**
	Mean			
Problem 1	1.85	2.26	1.59	**5.70**
Problem 2	2.44	2.37	1.67	**6.59**
Overall Mean	**2.15**	**2.32**	**1.63**	**6.15**

Note: Planning (3-point scale), Monitoring (4-point scale), Evaluating (3-points scale)

In Problem 1, planning (M = 1.85), monitoring (M = 2.26), and evaluation (M = 1.59), with an overall M = 5.70, indicated a moderate level. Similarly, in Problem 2, planning (M = 2.44), monitoring (M = 2.37), and evaluation (M = 1.67), with an overall M = 6.59, indicated moderate levels. In sum, the mean scores for the two non-routine problems, planning (M = 2.15), monitoring (M = 2.32), and evaluation (M = 1.63), with an overall M = 6.15, indicated moderate levels of metacognition. The results indicated that planning, monitoring, and evaluation were evident in the pre-service teachers' solutions across the two non-routine problems. Among the three processes, evaluation obtained the lowest mean score ($M = 1.63$), suggesting that verifying the correctness, completeness, and reasonableness of solutions was the least evident metacognitive process. While the pre-service teachers were generally able to begin the problems by identifying relevant information and choosing possible strategies, they were less consistent in evaluating their final answers. This finding was consistent with the written solutions and reflective journals, where several pre-service teachers stopped after obtaining an answer and provided limited evidence of checking, validating, or justifying their final solutions. Although monitoring obtained the highest mean score ($M = 2.32$), this finding should be interpreted with caution because monitoring was scored on a 4-point scale, whereas planning and evaluation were scored on 3-point scales. Nevertheless, the results suggested that many pre-service teachers demonstrated awareness of their progress while solving, particularly through trying strategies, identifying difficulties, revising procedures, and adjusting their approaches when necessary.

Overall, the findings indicated that the pre-service teachers were generally able to engage in planning and monitoring during problem-solving, but evaluation remained the least consistently demonstrated metacognitive process. The findings of the study support previous research emphasizing the importance of metacognitive processes in mathematical problem-solving. The moderate level of metacognition demonstrated by the pre-service teachers suggests that planning, monitoring, and evaluation were present but not consistently applied across all non-routine tasks. This finding is consistent with Schraw (1998), who emphasized that effective learners regulate their cognition through planning, monitoring, and evaluation. Similarly, Güner and Erbay (2021) found that students with stronger metacognitive skills were more likely to employ appropriate representations, strategies, and reasoning when solving non-routine mathematical problems. The findings also support Gurat and Medula (2016), who highlighted that successful problem solvers continuously monitor and evaluate their strategies throughout the solution process.

Metacognitive Processes of Pre-Service Teachers

To support the quantitative results, selected written solutions and direct statements from the reflective journals of pre-service teachers classified under high, moderate, and low levels of metacognition were examined. The analysis focused on how they demonstrated planning, monitoring, and evaluation in the two non-routine problems used to measure metacognition.

In Problem 1, Sally invited 17 guests to a Christmas show and assigned each guest a number from 2 to 18 while keeping 1 for herself. The task required the pre-service teachers to determine Sally's partner's number under the condition that the sum of each couple's numbers was a perfect square. In Problem 2, the pre-service teachers analyzed a square-pattern orchard with apple trees and surrounding conifer trees and determined which quantity would increase more quickly as the orchard became larger.

High Level of Metacognition

To illustrate the processes exhibited by pre-service teachers with a high level of metacognition, the written solutions and reflective journal responses of P11 and P14 were examined. These secondary mathematics pre-service teachers were selected because they obtained high metacognition scores and demonstrated clear evidence of planning, monitoring, and evaluation while solving the non-routine problems.

Problem 1.

Planning was evident when P11 initially considered different approaches and later adopted a more systematic strategy using sets and organized pairings. As reflected in the journal, *"My plan at first was doing trial and error, but later on I came to realize that by using sets I can assign them to be perfectly paired to each other."* Rather than focusing only on Sally's partner, P11 considered the conditions that must be satisfied by all guests. *Monitoring* was demonstrated as P11 continuously examined possible pairings, identified difficulties, and adjusted the strategy when necessary. This was reflected in the statement, *"I did become stuck… it took me some time to solve the problem… from trial and error, I resorted to using sets to see the possible numbers to pair."* This indicated awareness of difficulties and active regulation of the solution process. *Evaluation* was evident when P11 checked whether all pairs formed perfect squares and ensured that no number was repeated. As stated in the journal, *"I added numbers and cross-checked to see if the numbers I paired up did not repeat."* This indicated that P11 verified the correctness and completeness of the solution before arriving at the final answer. Thus, P11's solution reflected high level metacognition because they were able to plan a systematic approach, monitor the solution process, and evaluate the completeness of the final answer.

Problem 2.

Planning was evident when P14 generated values for different cases of n and organized the observed pattern. From these values, P14 identified the expressions $8n$ for the conifer trees and n^2 for the apple trees. This showed that P14 did not rely solely on visual inspection but first organized the given information to establish a mathematical representation. This was supported by the reflective journal, where P14 stated that the strategy used was *"using formula and comparing both variables."* *Monitoring* was demonstrated when P14 tested values of n, observed the relationships, and adjusted the approach while identifying the formulas. As reflected in the journal, *"I became stuck in identifying the formulas, and I handled it using trial and error."* This indicated that P14 was aware of the difficulty and regulated the solution process by testing possible patterns. *Evaluation* was evident when P14 compared the formulas using larger values, such as n=10, to verify which quantity increased more quickly. As stated in the journal, *"I used the derived formulas and compared them with different values."* This showed that P14 checked whether the conclusion remained valid beyond the values shown in the diagram. Thus, P14's solution reflected high level metacognition because the participant was able to plan through pattern organization, monitor the development of formulas, and evaluate the conclusion using additional values.

Moderate Level of Metacognition

To illustrate the processes exhibited by pre-service teachers with a moderate level of metacognition, the written solutions and reflective journal responses of P5 and P24 were examined. These pre-service teachers were selected because they obtained a moderate level of metacognition performance and showed evidence of planning and some monitoring but demonstrated limited evaluation in the solution process.

Problem 1.

Planning was evident when P5 identified the goal of forming pairs whose sums were perfect squares. P5 organized selected number combinations and used a clear strategy of pairing numbers to obtain a perfect-square sum. This was reflected in the journal statement, *"I add a number that would be equal to a perfect square."* *Monitoring* was partially demonstrated when P5 followed the chosen strategy and checked some combinations while solving. However, the monitoring process was not fully sustained because the solution focused mainly on selected pairings and did not show a complete examination of all possible guest pairings. *Evaluation* was limited. Although P5 claimed to have checked the solution by ensuring *"that the sum of every couple is a perfect square,"* the written solution showed incomplete verification because not all guests were paired and checked according to the full condition of the problem. Thus, P5's solution reflected moderate level metacognition because planning was evident and monitoring was partially shown, but evaluation was not fully demonstrated.

Problem 2.

Planning was evident when P24 began by examining the diagram and identifying the visible pattern in the number of trees. As reflected in the journal, *"First, I looked at the diagram provided and analyzed it."* This showed that P24 attempted to understand the given representation and use it as a basis for the solution. *Monitoring* was partially demonstrated when P24 observed that the number of conifer trees increased by 8 for each value of n. However, the monitoring process was limited because the participant relied mainly on the visible values in the diagram and did not test whether the observed pattern would still hold for larger values. *Evaluation* was limited because P24 concluded that conifer trees increased more quickly based only on the given diagram. As stated in the journal, *"I just checked the diagram that was provided, and it is clear what increases quickly."* This indicated that the conclusion was not fully verified, since the long-term comparison between $8n$ and n^2 was not considered. Thus, P24's solution reflected moderate level metacognition because planning was evident and monitoring was partially shown, but evaluation was incomplete.

Low Level of Metacognition

To illustrate the processes exhibited by pre-service teachers with a low level of metacognition, the written solutions and reflective journal responses of P12 and P2 were examined. These pre-service teachers were selected because they obtained a low level of metacognition performance and showed weak evidence of planning, monitoring, and limited evaluation in the solution process, and often misunderstood the problem.

Problem 1.

Planning was weak because P12 misunderstood the condition of the task. Instead of determining pairs whose sums formed perfect squares, P12 focused on squaring individual numbers. This was reflected in the journal statement, *"I tried to square each number of her guests ... then I tried to answer it, and the answer is 1."* This showed that the chosen strategy did not match the mathematical condition of the problem. *Monitoring* was limited because P12 did not recognize that the strategy used did not satisfy the problem requirement. The participant continued with an incorrect interpretation of the perfect-square condition and did not adjust the approach during the solution process. *Evaluation* was also weak because P12 did not sufficiently verify whether all guests were paired correctly and whether the sums of the pairs formed perfect squares. Although P12 expressed confidence in the answer because *"I used perfect square,"* the written solution showed that the participant interpreted the condition as squaring Sally's number rather than checking the sum of each pair. This indicated limited checking of the correctness and completeness of the final answer. Thus, P12's solution reflected low level metacognition because they used an incorrect plan, showed limited monitoring of the solution process, and did not adequately evaluate whether the final answer satisfied the conditions of the problem.

Problem 2.

Planning was weak because P2 did not clearly identify the relevant pattern needed to compare the growth of conifer trees and apple trees. Although P2 stated in the reflective journal that the strategy was *"using algebra skills,"* the written solution did not clearly show how algebra was used to compare the two quantities. *Monitoring* was limited because P2 did not examine whether the observed pattern remained valid for larger values. Instead, the solution appeared to rely mainly on the visible or immediate values in the diagram. This suggested that P2 did not sufficiently track the progress or adequacy of the strategy during the solution process. *Evaluation* was insufficient because P2 did not test larger values of (n) or examine the general behavior of (8n) and (n^2). Although P2 stated that the answer was checked by *"just applying algebra and comparing the given example,"* the checking process remained limited to the given examples. This led to an incorrect conclusion and showed weak verification of the final answer. Thus, P2's solution reflected low level metacognition because the participant did not clearly establish the general pattern, showed limited monitoring of the comparison process, and did not sufficiently evaluate the conclusion using larger values of n.

Overall, the qualitative evidence supported the quantitative finding that the pre-service teachers demonstrated a moderate level of metacognition. Under the high level of metacognition, the pre-service teachers showed more complete planning, monitoring, and evaluation by organizing information, shifting from less efficient strategies to more systematic approaches, checking conditions during the solution process, and verifying the completeness of their conclusions. Under the moderate level of metacognition, the pre-service teachers showed partial or developing metacognition, particularly in understanding the task and using initial strategies; however, their monitoring and evaluation were not consistently sustained, as some stopped after identifying a possible answer or relied solely on visible patterns without testing further cases. Under the low level of metacognition, the pre-service teachers tended to misunderstand problem conditions, rely on inappropriate or surface-level strategies, and provide limited verification of their answers. These findings suggested that although the pre-service teachers demonstrated metacognitive processes during non-routine problem solving, the depth, accuracy, and consistency of their planning, monitoring, and evaluation varied across participants and tasks.

CONCLUSION AND PRACTICAL IMPLICATIONS

The study concluded that the pre-service mathematics teachers demonstrated a moderate level of metacognition in solving non-routine mathematical problems. Planning, monitoring, and evaluation were evident in their written solutions and reflective journals; however, these metacognitive processes were not consistently demonstrated across all participants and tasks. Among the three processes, evaluation emerged as the least evident, indicating that many pre-service teachers experienced difficulty verifying the correctness, completeness, and reasonableness of their solutions. Pre-service teachers with a high level of metacognition demonstrated systematic planning, active monitoring, and careful evaluation, whereas those with a moderate level of metacognition showed partial regulation of their thinking. In contrast, pre-service teachers with a low level of metacognition often misunderstood problem conditions, relied on inappropriate or surface-level strategies, and provided limited verification of their answers. Overall, the findings suggested that while pre-service teachers possess developing metacognitive abilities, further support is needed to strengthen their evaluation skills and promote more reflective and effective engagement in non-routine mathematical problem-solving.

The findings have important implications for mathematics teacher education. Teacher educators may explicitly integrate metacognitive instruction into problem-solving activities by incorporating planning prompts before solving, monitoring checklists during the solution process, and evaluation questions after completing a task. Examples of prompts include: What information is given? What strategy will I use? Is my strategy working? Have I checked all conditions? Is my answer reasonable? Teacher educators can also use reflective journals, solution-verification activities, think-aloud strategies, and discussions of multiple solution methods to help pre-service teachers become more aware of their thinking processes. Since evaluation was the least consistently demonstrated metacognitive process, greater emphasis should be placed on checking the validity, completeness, and reasonableness of solutions rather than focusing solely on obtaining correct answers. Strengthening these metacognitive skills may better prepare future mathematics teachers to facilitate reflective, strategic, and meaningful problem-solving among learners in K–12 mathematics classrooms. Future studies may use larger samples, include multiple institutions, and apply inferential tests to examine whether differences between tasks or level distributions are statistically meaningful.

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