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The effect of metacognitive abilities on junior high school students in the Republic of Vanuatu when solving mathematical word problems.

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Abstract

Mathematics achievements in Vanuatu remain a major concern for mathematics education within the Vanuatu education system. The level of students' ability to reflect on their thinking processes and choose an effective strategy to solve a problem is an indicator that requires immediate attention to exploring possible solutions. Along this line, this study was intended to investigate the use of metacognitive abilities and their effectiveness in solving mathematics word problems among Junior High School students in the Republic of Vanuatu. Metacognitive abilities, which are often described as "thinking about one's thinking," encompass two categories. The first is metacognitive knowledge, which refers to people, tasks, and strategies. The second is metacognitive skills, which comprise self-monitoring, self-evaluation, and self-control. The study compares the effectiveness of these metacognitive abilities among 39 grade eight students and 28 grade nine students of Kawenu Junior High School in Port Vila, Vanuatu. One non-routine word problem was used similarly in both grades. The problem-solving process involves quadratic equations. The responses from students were assessed from the six perspectives described above. The findings revealed 62% of correct responses in year eight, while 68% of correct responses were obtained in year nine. These results indicated that correct responders rely more on their cognitive strengths during problem-solving, likely drawing on prior knowledge or automaticity, while incorrect responders struggle to apply effective cognitive strategies, even when they engage in pre-solution metacognitive activities. Furthermore, according to the Grounded Theory Approach used for the analysis of this study, the examples of students' responses observed demonstrated that when metacognition is used effectively, it helps students connect new problems to previously learned material, engage in self-reflection, and monitor their problem-solving strategies. On the other hand, when metacognition is either absent or improperly used, students struggle to articulate clear strategies or fail to connect their reasoning to underlying mathematical concepts.

Keywords: Mathematical word problems, Metacognition, Metacognitive abilities, Metacognitive knowledge, Metacognitive skill, Vanuatu.

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1. Introduction to Metacognition

Metacognition, often described as "thinking about one's thinking," has been a widely researched area in educational psychology since the term was introduced by Flavell [1]. It refers to individuals' ability to monitor, regulate, and control their cognitive processes. In recent years, the significance of metacognition has grown in an increasingly uncertain world, as emphasized by UNESCO [2] call for educational systems to foster critical thinking and adaptability to navigate complex global challenges [2]. Research in educational psychology also supports the importance of metacognitive skills, showing that students who are aware of their cognitive processes tend to perform better academically and are more resilient in the face of uncertainty [3, 4]. In addition, recent studies have emphasized the need to consider cultural and contextual factors when examining the role of metacognitive skills in education. In developing countries, where educational resources may be limited, fostering metacognitive skills can empower students to become more independent learners and make better use of available resources [5]. However, the effectiveness of metacognitive strategies may vary across different cultural contexts, as students' learning habits and attitudes towards problem-solving are shaped by their cultural background. Therefore, it is essential for educators to adapt metacognitive instruction to suit the needs and preferences of students from diverse cultural settings. Most studies have focused on students in Western countries, with limited research conducted in developing countries like Vanuatu. Additionally, while many studies have explored the relationship between metacognition and problem-solving performance, fewer studies have examined the specific challenges students face in applying metacognitive strategies to non-routine problems. Although there is substantial evidence supporting the benefits of metacognitive skills in mathematics education, several gaps remain. This study aims to explore the metacognitive abilities of middle school students in the Republic of Vanuatu.

2. Literature Review

2.1. Importance of Metacognitive Abilities in Mathematics Education

Metacognitive abilities are increasingly recognized as fundamental to effective mathematics education, enabling students to plan, monitor, and evaluate their cognitive processes during problem-solving. These abilities go beyond basic cognitive abilities like calculation and logical reasoning, emphasizing the ability to reflect on one's strategies, adapt to new challenges, and regulate one's learning [4, 6]. In mathematics, problem-solving often involves tackling complex, non-routine tasks that require creativity, persistence, and flexibility, making metacognitive awareness vital for success [7]. Research consistently shows that students with strong metacognitive skills perform better in mathematics. For example, Desoete and De Craene [8] highlight that students who actively engage in self-monitoring and strategy adjustment during problem-solving tend to achieve better outcomes and demonstrate higher levels of comprehension. Moreover, these students are more likely to persist through difficulties and approach problem-solving as a reflective, iterative process rather than merely executing learned procedures [9]. This ability to self-regulate is particularly beneficial for tackling non-routine problems, where students must choose and adapt strategies based on the unique demands of the task [10]. Furthermore, metacognitive skills are closely tied to deeper, more meaningful learning in mathematics. When students are encouraged to reflect on their thinking and problem-solving approaches, they develop a greater understanding of mathematical concepts. As Whitebread and Blair and Raver [11] argue, students who engage in metacognitive activities are more likely to retain knowledge and apply it in novel situations. This process of self-regulation fosters the ability to think critically and adaptively, allowing students to develop flexible problem-solving strategies that can be transferred across different types of tasks [12]. Metacognitive skills also foster independent learning, which is essential for lifelong success in mathematics. Students who can regulate their cognitive processes are better equipped to learn autonomously, without excessive reliance on teachers or peers. This independence not only enhances mathematical competence but also promotes a growth mindset, where students view challenges as opportunities for development rather than as insurmountable obstacles. Independent learners can self-assess their progress, set meaningful goals, and seek out resources to improve their understanding [13]. Additionally, research shows that teaching metacognitive strategies in the classroom leads to significant improvements in student outcomes. When students receive explicit metacognitive training, such as learning how to plan, monitor, and evaluate their problem-solving approaches, they become more effective problem solvers. Similarly, studies by Dignath and Büttner [14] indicate that incorporating metacognitive scaffolding in digital learning environments enhances students' ability to manage complex tasks and improves their overall mathematical achievement.

In conclusion, metacognitive skills are essential for mathematics education because they enable students to become reflective, adaptive, and independent problem-solvers. By fostering the development of these skills, educators can help students improve their mathematical performance, deepen their conceptual understanding, and approach challenges with confidence and resilience. The integration of metacognitive instruction in mathematics classrooms can therefore lead to more effective learning and greater long-term success for students.

2.2. Components of Metacognitive Skills

The categorization of metacognitive skills into distinct components has been the result of decades of theoretical development and empirical research. The roots of metacognitive theory can be traced back to the work of Flavell [3] who was among the first to introduce the term "metacognition" in the context of cognitive development. Flavell distinguished between *metacognitive knowledge* and *metacognitive experiences*, where metacognitive knowledge referred to an individual's understanding of their own cognitive processes, including their awareness of tasks and strategies. His initial work laid the foundation for a more nuanced understanding of how learners monitor, control, and reflect on their thinking.

Flavell [1] model, while groundbreaking, did not explicitly separate the regulation of cognition from the knowledge about cognition, which limited the application of his framework to problem-solving contexts. Subsequent research sought to refine these ideas and provide clearer distinctions between different types of metacognitive skills. Building on Flavell [3] early insights, Brown [15] significantly expanded the theoretical framework of metacognition by introducing the idea of *regulation of cognition*. Brown identified key regulatory processes—*planning*, *monitoring*, and *evaluation*—as essential components of metacognitive activity. Her work was influential in shaping the way researchers and educators understood how learners actively manage their cognitive processes, particularly in learning and problem-solving situations. Brown's emphasis on the dynamic, self-regulatory aspects of metacognition marked a significant step in moving beyond Flavell's foundational but broad conceptualization. In their influential work, Schraw and Moshman [4] proposed a more structured and detailed model of metacognition, dividing it into two key components: *metacognitive knowledge* and *metacognitive regulation*. Their framework is widely regarded as a seminal contribution to the field of educational psychology. Table 1 shows the types of metacognitive knowledge. According to Schraw and Moshman [4] metacognitive knowledge consists of three subtypes: Person knowledge, task knowledge, and strategy knowledge. Person knowledge refers to learners' awareness of their cognitive strengths and weaknesses. This includes an understanding of when and where they perform well, such as recognizing that they struggle with certain types of mathematical problems but excel in others. *Task knowledge* involves understanding the nature of a task, including its complexity and the cognitive demands it places on the learner. For example, recognizing whether a problem is routine or requires novel problem-solving approaches is a critical aspect of task knowledge. Finally, *strategy knowledge* refers to learners' understanding of which cognitive strategies are most effective for specific tasks. This might include the ability to break a problem into smaller steps or using visual aids to better comprehend complex information.

Table 1.
Metacognitive knowledge.

Types	Meaning		Example
Person	Knowledge about oneself	Knowledge about one's own cognitive characteristics	I am good at calculating fractions, but I struggle with decimals.
		Knowledge about cognitive characteristics among individuals	Person A is better at math than Person B.
		Knowledge about general cognitive characteristics	Consistent learning tends to be more effective than studying all in one night.
Task	Recognition about the task	Knowledge about the inherent characteristics of the task itself.	Word problems take more time and are more difficult than simple operation problems.
Strategy	Understanding about the strategies	Declarative knowledge	Using equation is good for solving the problem.
		Procedural knowledge	I know how to apply equation in this problem.
		Conditional knowledge	I can explain when and the reason why I use equation.

Table 2 shows the types of metacognitive regulation. .*Metacognitive regulation*, the second major component of Schraw and Moshman [4] model, includes three key processes: *Planning*, *monitoring*, and *evaluation*. *Planning* involves selecting strategies and allocating cognitive resources before engaging with a problem. Learners who effectively plan are able to set goals, choose appropriate strategies, and sequence their actions before diving into problem-solving. *Monitoring* refers to the ongoing process of tracking one's progress during the task, ensuring that chosen strategies are effective, and making adjustments if necessary. For instance, a learner may monitor their problem-solving process by asking themselves whether their approach is leading them closer to a solution or if they need to revise their strategy. Finally, *evaluation* occurs after the problem is solved and involves reflecting on the effectiveness of the chosen strategies and the accuracy of the solution. Learners who engage in evaluation are able to determine what worked, what didn't, and how they might approach similar problems in the future.

Veenman, et al. [16] further refined the concept of metacognitive regulation by emphasizing the intertwined nature of metacognition and cognitive ability. They argued that while metacognitive skills can operate independently, they are often integrated with cognitive processes, making it difficult to separate the two. Their research demonstrated that metacognitive skills are not just add-ons to cognition but are deeply embedded within cognitive tasks. This underscores the importance of teaching learners how to regulate their cognitive activities through planning, monitoring, and evaluation, rather than merely providing them with knowledge about cognitive strategies.

Table 2.
Metacognitive regulation.

Types	*Meaning*	*Examples*
Monitoring	The act of person monitoring their thought processes and their outcomes during problem-solving.	I think I still don't fully understand this problem.
Control	The act of person modifying and regulating their problem-solving actions based on their self-evaluation.	I think it is better to think from different points of view and use different examples.
Evaluation	The act of person evaluating their problem-solving process or its results by themselves.	I think there is easier and more effective way to solve this problem.

2.3. Challenges in Measuring Metacognition in Mathematical Problem-Solving

Measuring metacognition in mathematical problem-solving presents significant challenges due to the internal nature of metacognitive processes such as planning, monitoring, and evaluating. These processes are crucial for successful problem-solving as they allow students to assess their approach, track progress, and adjust strategies as needed. However, because these activities primarily occur within the mind, they are difficult to observe directly. In mathematics, metacognitive actions often include reflecting on strategies, checking calculations, and evaluating whether the solution meets the problem's requirements. Given these challenges, researchers have developed several indirect methods to measure metacognition, such as self-report questionnaires, think-aloud protocols, and structured interviews [17, 18]. While these approaches provide valuable insights, they also have limitations, as they rely heavily on students' ability to articulate their internal thought processes accurately, which may not always align with their actual metacognitive engagement. To address the limitations of these traditional methods, recent research has emphasized the need for more structured, yet flexible, tools to measure metacognitive engagement quantitatively. One promising approach is the use of open-ended questions that allow students to express their problem-solving strategies in detail. These questions enable students to describe how they planned their approach, monitored their progress, and evaluated their final solution [19]. To evaluate these responses effectively, rubrics have been developed to assess the depth of metacognitive engagement, focusing on key aspects such as whether students outlined a clear strategy before beginning the problem, regularly checked their work, and critically evaluated the final solution for accuracy and alignment with the problem's requirements [20]. However, developing rubrics for measuring metacognition is not without its challenges. One of the primary difficulties is distinguishing between superficial engagement, such as basic checks for accuracy, and deeper, more reflective engagement, such as reconsidering the overall approach to the problem [7]. Researchers like Veenman [19] have attempted to address this issue by creating rubrics that assess multiple layers of metacognitive activity, allowing for a more nuanced evaluation of students' reflective processes. Nevertheless, creating reliable and valid rubrics that capture the full range of metacognitive behavior remains an ongoing challenge, particularly in diverse educational settings where cultural differences may influence how students engage in problem-solving and reflection.

2.4. Metacognition in Polya's Four Steps of Problem Solving

Table 3 shows the Metacognition in Polya's Four Steps of Problem Solving. Polya's four-step problem-solving model provides a clear structure for understanding how students utilize metacognitive strategies in mathematical problem-solving. These four stages—(1) Understanding the Problem, (2) Devising a Plan, (3) Carrying Out the Plan, and (4) Examining the answer —each offer opportunities for students to engage in reflective thinking that enhances their ability to solve problems effectively. In the first stage, Understanding the Problem, metacognitive strategies such as *self-questioning* and *self-monitoring* play a critical role. As Greene and Azevedo [18] highlight, successful problem solvers frequently ask themselves if they fully understand the problem's requirements and reflect on the information provided before moving forward. In the second stage, Devising a Plan, students need to engage in *strategic planning* and *goal-setting*, determining which methods and tools are most appropriate for solving the problem. Goos, et al. [21] emphasize that students who engage in planning are more likely to select efficient strategies and avoid common errors. However, this process can vary depending on cultural context, as Lester and Cai [22] found in their cross-cultural studies of problem-solving approaches in different educational systems. In the third stage, Carrying Out the Plan, *self-regulation* and *self-monitoring* become vital, as students must continually assess whether their plan is working and make necessary adjustments along the way. Mevarech and Fridkin [23] noted that successful problem solvers frequently check their progress and are quick to revise their strategies when encountering difficulties. Finally, in the fourth stage, Looking Back, students use *self-evaluation* to reflect on the effectiveness of their approach and the accuracy of their solution. According to Desoete [24] this stage is essential for consolidating learning, as it allows students to reflect on what worked and what did not, thereby improving their problem-solving skills for future tasks. Recent studies confirm the importance of metacognitive strategies in mathematical problem-solving, emphasizing that teaching students to reflect on their thinking at each stage of Polya's model leads to improved performance and greater adaptability when faced with new, complex problems.

Table 3.
Metacognition in Polya's four steps of problem solving.

Problem-Solving Stage	***Cognitive***	***Metacognitive***		***Examples***
		Knowledge	***Regulation***	
Understanding the Problem	Understand the problem	Person Task		-Have I encountered a similar problem before? - I'm not good at reading graph.
Devising the plan	Formulate the mathematical sentence	Strategy		- I think I can use an equation for solving the problem. - What steps should be followed to solve it?
Carrying Out the Plan	Solve the problem		Monitoring Control	- Am I solving it correctly? - If it's not going well, can I solve it another way?
Examining the answer	Check the answer		Evaluation	- Can I explain the process of my answer? - Which part was the most challenging for me?

2.5. Research Objective and Question

This study aimed to investigate the use of metacognitive abilities and their effectiveness in solving mathematical word problems among the Junior High School students in the Republic of Vanuatu.
Two research questions were established for the study.

1) What metacognitive skills do high school students in the Republic of Vanuatu occupy when solving non-routine mathematical word problems?
2) What is the relationship between the correct answer rates for problems and metacognitive skills?

2.6. Research Design

2.6.1. Subject

The sample groups selected for the study were 39 grade eight students and 28 grade nine students from one Anglophone Public School in Port Vila in the Republic of Vanuatu. This urban-selected school has an enrolment of 400+ students beginning from kindergarten to grade nine. The school is an Indigenous Vanuatu citizen-dominated school, whereby most students attending the school come from surrounding communities. The curriculum delivered in the school is provided by the National Government through its Curriculum Development Unit (CDU).

2.6.2. Item Used

One non-routine problem was presented along with an illustration. The question requires solving using a quadratic equation. However, the problem is not found in the Vanuatu textbook.

2.6.3. Question

"The length of the swimming pool is 27 feet. Find the width of the pool if the area is 270 square feet?"

The question was a quadratic problem whereby students were to find the x which was the unknown width of the swimming pool. It was designed to encourage students to utilize metacognitive skills to address the situation through possible strategies surrounding the problem. The potential strategies of finding the x were hinted through the problem itself. For instance, the shape itself was identified a rectangular in the word problem. This gives students an image of using the formula for calculating the area to work out the unknown width of the swimming pool. The diagram of the pool itself enlightens the thinking surrounding the formula for calculating area. The unknown measurement of the width brings light to finding the x in an equation. Provided the fact that the area of the pool was given, it implies the opinion of dividing the area by the given length to find the unknown width which denotes the x in the quadratic equation. However, there was only one correct answer as $x = 10$. The x was obtained when the area of 270 square feet was divided by the length of 27 feet. It was then proven when the length of 27 feet multiplies the x which was calculated to be 10 feet to obtain 270 square feet.

2.7. Method of Data Collection and Analysis

Table 4 presents a framework developed by Kusaka and Ndihokubwayo [5] which aligns the types of metacognitive skills discussed in the literature review with the four stages of problem-solving. This framework was found to be very useful for analyzing the collected data, as the questions used for data collection pertain to both types of metacognitive skills and the four stages of problem-solving. For instance, questions 1, 2, 5, 6, 7, and 8 pertain to metacognitive skills, while questions 3 and 4 relate to cognitive skills. Among the metacognitive skill-related questions, questions 1, 2, and 5 address metacognitive knowledge, whereas questions 6, 7, and 8 address metacognitive regulation. Regarding the four stages of problem-solving, questions 1 and 2 focus on understanding the problem situation, questions 5 and 6 focus on executing the solution, and questions 7 and 8 focus on evaluating the solution. Scores were assigned to each question based on a two-tier criterion.

Table 4.
Analytical framework.

	Questions	Cognition	Metacognition		Score	Sub score	Criteria
			Metacognitive Knowledge	**Metacognitive regulation**			
1	"How confident you are in solving the problem, in terms of percentage? Why did you choose that number? Please explain the reason."		Person, Task		2	1	Vague reasons like "it seems difficult".
						2	Clear reasons such as relating to previously learned topics. One`s own strength.
2	What did you consider about strategy while reading the problem?		Strategy		2	1	Vague explanation about the strategy.
						2	Clear explanation about the strategy.
3	What did you understand after reading the problem?	Understand the problem			3	1	A total length is 24 cm.
						1	The front fence is 3m longer than the side fence.
						1	Finding the length of the side fence.
4	Solve the problem by freely drawing diagrams and equations.	Plan			3	1	Showing the relationship between the perimeter and the length of the horizontal fence.
		Executions				1	Making mathematical expression to find the answer.
		Result				1	The answer is correct.
5	Explain how you solve the problem.		Strategy		2	1	Vague explanation about the content.
						2	Clear explanation about the method.
6	What did you think about while solving the problem?			Self-monitoring	2	1	Vaguely controlling one`s own state during solving the problem.
						2	Specifically monitoring one`s own state during solving the problem.
7	Explain the difficult part when solving the problem. Did you take any measures against them?			Self-control	2	1	Vaguely controlling one`s own state during solving the problem.
						2	Specifically monitoring one`s own state during solving the problem.
8	"How confident are you that you solved the problem, in terms of percentage? Why did you choose that number? Please explain the reason."			Self-evaluation	2	1	Vague reasons such as "it seems difficult".
						2	A clear reason link to one`s cognitive behavior.

Source: Kusaka and Ndihokubwayo [5].

According to Kusaka and Ndihokubwayo [5] framework, Question 1 involves task and person-related metacognitive knowledge. Answers that reference previously learned content or personal strengths were awarded 2 points, while vague answers, such as "seems difficult," were given 1 point. Question 2 pertains to metacognitive knowledge regarding strategy. Similar to Question 1, vague answers were given 1 point, while clear, specific answers were awarded 2 points. Questions 3 and 4 relate to the cognitive aspect. They follow the four stages of problem-solving, with Question 3 involving the understanding of the situation and Question 4 covering planning, execution, and outcomes. Question 5 was related to metacognitive knowledge about strategy and assesses the ability to metacognitively understand one's own problem-solving approach. Question 6 evaluates self-monitoring based on reflections during the problem-solving process. Question 7 measures self-evaluation by asking about the most difficult parts of the task. Question 8 assesses confidence in solving the problem and the reasons for it, which also relates to self-evaluation.

3. Results and Discussions

3.1. Comparison Between Learners with Correct Answers and Learners with Incorrect Answers

Table 5 presents the average values for correct and incorrect responders in Year 8, while Table 6 shows the results for Year 9. The findings from both Year 8 and Year 9 offer insights into how correct and incorrect responders engage with metacognitive and cognitive strategies before and after solving problems. Specifically, the data indicate that correct responders tend to use less explicit metacognition before solving the problem, as reflected in their lower scores on questions 1 and 2, which assess pre-solution confidence and strategy planning. However, during the problem-solving process (questions 3 and 4), correct responders exhibit clearer use of cognitive abilities. In terms of post-problem-solving reflection (questions 5–8), there are nuanced differences between correct and incorrect responders in self-monitoring, control, and evaluation.

3.1.1. Pre-Problem Solving: Limited Metacognitive Engagement by Correct Responders

In Year 8, correct responders (62% of the cohort) showed lower average scores on question 1 (confidence in solving the problem) and question 2 (strategy planning) compared to incorrect responders. Specifically, correct responders averaged 0.00 on question 1, indicating they did not display explicit confidence or could not articulate reasons for their confidence. In contrast, incorrect responders had a significantly higher score of 1.00, suggesting they engaged more actively in self-reflection regarding their confidence levels. This pattern persists in question 2, where correct responders scored 0.41, compared to 0.79 for incorrect responders. The p-value of 0.00 confirms that these differences are statistically significant. Similarly, in Year 9, correct responders had a low score of 0.07 on question 1 and 0.36 on question 2, while incorrect responders showed higher scores (0.96 and 0.82, respectively), with p-values also showing statistical significance.

The findings from Year 8 and Year 9 reveal a counterintuitive relationship between metacognitive engagement and problem-solving success. Typically, one might expect that increased metacognitive reflection—such as assessing confidence and planning strategies—would lead to better problem-solving outcomes. However, the data shows that correct responders, those who solved the problems accurately, demonstrated lower levels of metacognitive engagement, particularly in confidence assessments (question 1) and strategy planning (question 2), compared to incorrect responders. This result challenges the conventional understanding of how metacognition influences mathematical problem-solving and suggests several important points for deeper consideration. First, these findings may indicate that experienced or skilled problem solvers tend to rely more on automatic processes or intuitive thinking, reducing their need for explicit metacognitive reflection. Research suggests that expert problem solvers often solve problems efficiently by accessing pre-existing schemas or mental models, bypassing the need for conscious strategy planning or confidence assessment [4, 19]. In these cases, correct responders may not need to explicitly assess their confidence or plan their strategy because their prior knowledge and familiarity with the problem allow them to rely on more automatic, streamlined processes. In contrast, incorrect responders may engage more deeply in metacognitive activities, such as self-reflection or planning, because they are less familiar with the problem or uncertain about their approach. However, as the results show, this metacognitive engagement does not necessarily lead to successful outcomes. This suggests that while metacognitive engagement is important, it must be paired with effective cognitive strategies and accurate knowledge to result in correct problem-solving.

Additionally, the higher metacognitive scores for incorrect responders may reflect overconfidence or inaccurate self-assessment. Research on metacognition often notes that lower-performing students can overestimate their abilities, a phenomenon known as the Dunning-Kruger effect [20]. These students may engage in self-reflection and confidence assessment, but their judgments about their competence or the complexity of the problem may be inaccurate, leading to ineffective strategies and ultimately incorrect answers. This suggests that it is not just the presence of metacognitive activities that matters, but the quality and accuracy of these reflections. Incorrect responders might be reflecting on their approach, but with mis-calibrated confidence, leading to poor outcomes despite their higher metacognitive engagement.

Furthermore, this pattern of results highlights the complex relationship between confidence, competence, and metacognitive awareness. Research indicates that while metacognitive strategies like planning and monitoring can improve problem-solving, their effectiveness depends on how well students can accurately assess their own abilities [25]. In this case, incorrect responders may have been engaging in reflective activities without accurately understanding their own weaknesses or the problem’s requirements. In contrast, correct responders, particularly those who found the problem more familiar, may have bypassed explicit reflection because their automatic or intuitive processes were sufficient for solving the problem efficiently. This suggests that metacognitive engagement is beneficial, but only when aligned with accurate self-assessment and effective problem-solving strategies.

These findings challenge the simplistic notion that more metacognitive engagement always leads to better problem-solving performance. Instead, they highlight the importance of the accuracy and quality of metacognitive processes. Incorrect responders engaged more in metacognitive activities, such as confidence assessment and strategy planning, but their engagement was not effective, likely due to overconfidence or ineffective cognitive strategies. Conversely, correct responders, particularly those with more experience, may rely on intuitive processes, solving problems accurately without extensive metacognitive reflection. This suggests that instructional interventions should focus not only on increasing metacognitive engagement but also on improving the accuracy of self-assessment and fostering the development of effective problem-solving strategies.

3.1.2. Problem Solving (Cognitive Engagement): Clear Differences in Cognitive Strategies

When examining cognitive engagement during the problem-solving phase (questions 3 and 4), correct responders demonstrate significantly stronger cognitive abilities. In Year 8, correct responders scored 3.00 on both question 3 (understanding the problem after reading) and question 4 (problem-solving using diagrams and equations), indicating that they effectively grasped and applied the necessary cognitive strategies. In contrast, incorrect responders scored 0.59 on question 3 and 0.38 on question 4, showing weaker cognitive performance. The statistical significance of these differences is supported by p-values of 0.03 for question 3 and 0.00 for question 4. A similar pattern emerges in Year 9, with correct responders scoring 3.00 on both questions, while incorrect responders scored 0.82 on question 3 and 0.32 on question 4. These differences are also statistically significant, with p-values of 4.26 and 0.00, respectively. These results reinforce the idea that correct responders rely more on their cognitive strengths during problem-solving, likely drawing on prior knowledge or automaticity, while incorrect responders struggle to apply effective cognitive strategies, even when they engage in pre-solution metacognitive activities.

3.1.3. Post-Problem Solving: Variations in Self-Monitoring, Control, and Evaluation

After solving the problem, the data show notable differences in how correct and incorrect responders reflect on their process (questions 5–8). In Year 8, in questions 7 and 8, which pertain to self-control (question 7) and self-evaluation (question 8) in post-problem-solving stages, incorrect responders showed higher average scores compared to correct responders (0.79 vs. 0.41 for question 7 and 0.95 vs. 0.05 for question 8). However, despite these higher scores for incorrect responders, the differences were not statistically significant, as indicated by the p-values (0.31 for question 7 and 1.14 for question 8). These results suggest that incorrect responders engage more actively in post-solution reflection, potentially indicating their awareness of the difficulties they faced during the problem-solving process. This heightened reflection may reflect their attempts to explain or rationalize their incorrect solutions, even though these efforts did not translate into improved problem-solving performance. In contrast, correct responders, who may have relied on automatic or well-developed cognitive strategies, engaged less in these post-solution metacognitive processes. This reduced need for post-problem reflection in correct responders likely stems from their confidence in having already successfully navigated the problem-solving process.

A particularly noteworthy result emerges in question 6, which assesses self-monitoring during the problem-solving process. Incorrect responders scored significantly higher (0.87) compared to correct responders (0.26), with the p-value of 0.00 confirming that this difference is statistically significant. This result suggests that incorrect responders were more engaged in metacognitive monitoring, possibly indicating their awareness of the challenges they faced while attempting to solve the problem. The higher self-monitoring score for incorrect responders could imply that they were actively trying to find a solution, reflecting on their progress and assessing their strategies more frequently than correct responders. However, the fact that this increased self-monitoring did not lead to correct answers suggests that their metacognitive regulation was not effectively aligned with the cognitive strategies required for successful problem-solving. In other words, while incorrect responders may have been thinking about the problem-solving process, they were unable to identify or implement the correct strategies to solve the problem.

The most striking result is found in question 5, which assesses metacognitive knowledge related to strategy. In this case, correct responders scored higher (0.77) compared to incorrect responders (0.62), and the difference is statistically significant with a p-value of 0.00. This result highlights a critical aspect of metacognitive engagement: correct responders not only applied effective strategies to solve the problem but also demonstrated a better ability to explain and reflect on the processes that led to their correct solutions. This finding suggests that correct responders possess a more refined understanding of the problem and their approach to solving it. Their ability to articulate their problem-solving process indicates that they were able to consciously apply and reflect on their strategies, which likely contributed to their success. In contrast, incorrect responders, despite being more engaged in self-monitoring and reflection, lacked the clarity and precision in their metacognitive knowledge needed to solve the problem correctly.

The analysis of questions 5 to 8 for Year 9 reveals similar results to those observed in Year 8, with clear differences between correct and incorrect responders in their post-solution metacognitive engagement. Correct responders consistently demonstrate stronger abilities in question 5, which assesses metacognitive knowledge related to strategy, scoring 0.93 compared to 0.54 for incorrect responders, indicating that correct responders have a better understanding of the strategies they used and can articulate them effectively. However, in question 6 (self-monitoring), incorrect responders scored significantly higher at 0.82 compared to 0.36 for correct responders, with a statistically significant p-value of 0.00. This suggests that incorrect responders engage more in monitoring their process during problem-solving, likely reflecting their uncertainty or struggle to find the correct approach. Similarly, for question 7 (self-control), incorrect responders again outscored correct responders (0.71 vs. 0.57), and in question 8 (self-evaluation), incorrect responders showed a much higher score of 0.96 compared to just 0.07 for correct responders, indicating that incorrect responders engage more in evaluating their performance after solving the problem. However, despite their higher engagement in post-solution reflection, incorrect responders' higher scores do not translate into successful problem-solving, suggesting that their metacognitive regulation, while frequent, is ineffective. Correct responders, on the other hand, engage less in post-solution reflection but are more successful in problem-solving, likely due to their stronger metacognitive knowledge and cognitive strategy application during the problem-solving process itself. As in Year 8, these results suggest that while incorrect responders engage more in metacognitive activities, it is the quality of their reflection, rather than the quantity, that affects their ability to solve problems correctly.

A deeper look at question 5 highlights a crucial aspect of metacognitive engagement: explanatory power or the ability to clearly articulate one's problem-solving process, a skill often associated with metacognitive knowledge. Previous studies suggest that correct responders likely possess a more refined internal schema or mental model that guides their problem-solving actions [16]. These internal models, honed through experience and practice, allow correct responders to retrieve appropriate strategies and solutions with minimal cognitive load, allowing them to concentrate more on solution articulation rather than mere discovery. The higher scores of correct responders on question 5 indicate their ability to effectively verbalize this internalized knowledge, supporting the notion that successful problem solvers exhibit well-developed metacognitive knowledge that enables them to explain their strategies in detail, reinforcing their problem-solving success [24]. Conversely, incorrect responders, despite engaging in high levels of post-solution reflection (as evidenced by higher scores in questions 6 to 8), scored lower on question 5. This discrepancy indicates a gap between the quantity and quality of their reflection. While they are actively engaged in self-monitoring, control, and evaluation, incorrect responders may lack the clarity or accuracy needed to reflect meaningfully on their strategy use. This misalignment has been observed in prior research, where students with less effective metacognitive regulation often fail to identify the flaws in their approach due to limited explanatory power and self-assessment accuracy [25]. For these students, higher metacognitive scores in questions 6 to 8 may reflect an effort to rationalize their process rather than a productive analysis aimed at improvement.

Table 5.
Results by Correct and Incorrect Answers - Year 8.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total (1,2,5,6,7 &8)**	**Total (3 & 4)**	**Total**
Learners who answered correctly (n = 24, 62 %)	0.00	0.41	0.00	3.00	0.77	0.26	0.41	0.05	0.32	1.04	0.50
Learners who answered incorrectly (n = 15, 38 %)	1.00	0.79	0.59	0.38	0.62	0.87	0.79	0.95	0.84	0.49	0.75
p-value	0.00	0.00	0.025	0.00	0.87	0.00	0.31	1.14	8.66	8.59	3.08

Table 6.
Results by Correct and Incorrect Answers – Year 9.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total (1,2,5,6,7 &8)**	**Total (3 & 4)**	**Total**
Learners who answered correctly (n = 19, 68 %)	0.07	0.36	0.00	3.00	0.93	0.36	0.57	0.07	0.39	1.34	0.63
Learners who answered incorrectly (n = 9, 32 %)	0.96	0.82	0.82	0.32	0.54	0.82	0.71	0.96	0.80	0.57	0.75
p-value	0.00	0.03	4.26	0.00	0.00	0.00	0.00	0.00	0.00	4.04	4.02

3.2. Example of the Answers

In regards to the importance of metacognition in this study, Table 7 presents specific examples for each stage of problem-solving, showing how metacognition is appropriately used according to the scoring used.

3.2.1. Detailed Analysis of Students' Use of Metacognition in Problem Solving

The role of metacognition in problem-solving is central to understanding how students' approach and reflect on mathematical tasks. The specific examples provided in Table 7 highlighted distinct differences in how metacognitive strategies are employed by students who either answer correctly or incorrectly. These examples demonstrate that when metacognition is used effectively, it helps students connect new problems to previously learned material, engage in self-reflection, and monitor their problem-solving strategies. However, when metacognition is either absent or improperly used, students struggle to articulate clear strategies or fail to connect their reasoning to underlying mathematical concepts.

For instance, when asked about their confidence in solving a problem (Question 1), students who did not utilize metacognitive strategies gave vague reasons, such as "I don't understand the problem when I am reading it" or "the problem is very hard for me to solve." These responses reveal a lack of reflection on their own understanding or prior knowledge, suggesting that they are not effectively evaluating their own capabilities or drawing on past learning experiences. On the other hand, students who used metacognition gave responses like, "I know a little bit based on what I learned in our math class," indicating that they were consciously linking the problem to prior knowledge. This is a critical aspect of metacognition—successful students were able to evaluate their confidence not just based on surface impressions of the problem's difficulty, but by considering how the current problem relates to what they have already learned.

Similarly, in response to Question 2, which asks about strategy considerations while reading the problem, students who did not use metacognition again gave vague responses such as, "this problem is too hard for me." This type of answer indicates a passive approach to the problem; the student recognizes difficulty but fails to engage with the problem in a way that allows for strategic planning. Conversely, students who demonstrated metacognitive awareness provided responses like, "when reading the problem, I notice that one length of the pool is 27 feet, and the width is the x that I will need to work out." Here, the student is actively processing the information presented in the problem, demonstrating a clear understanding of how to begin formulating a strategy. This indicates the student is not only comprehending the problem but also beginning to plan a solution, a hallmark of effective metacognitive regulation.

The differences between metacognitive and non-metacognitive responses become even more evident in Question 3, which asks students to explain what they understood after reading the problem. Non-metacognitive students provided responses like, "when I read the problem, I got confused," or "I don't understand how to calculate." These responses reflect a lack of engagement with the problem's structure and an inability to break the problem down into manageable parts. In contrast, students using metacognition gave more detailed responses, such as, "after reading the problem, I understand that the length of the swimming pool is 27 feet, and that if I find the width of the pool, the total will be 270 square feet." This type of response shows that the student has not only understood the given information but is already working toward a solution by identifying the key relationships between the numbers involved. Such responses demonstrate the student's ability to extract relevant details and use them to plan a path toward the solution, which is a key aspect of metacognitive problem-solving.

The use of metacognition during the problem-solving process itself (as evaluated by Question 5) further illustrates the distinction between students who succeed and those who struggle. Some students, particularly those who did not employ metacognition, gave answers like, "I just add zero to the 27, and it becomes 270," indicating that they misunderstood the problem or applied a superficial strategy without considering the logic of their approach. In contrast, students who used metacognition responded with clear explanations such as, "I use the formula of a rectangle which is L x W. First, we have to find the width, which is the x, so 27 times x gives the number of 270. x = 10. So we go 27 times 10, and it will give you the answer." This detailed response shows that the student is not only following a mathematical procedure but also explaining each step of their thinking, ensuring that their approach is valid. Metacognition, in this case, allows the student to reflect on their strategy and verify its correctness, which is a crucial element of successful problem-solving.

Regarding Question 6, which focuses on the students' thoughts during problem-solving, non-metacognitive responders tended to provide limited insights into their cognitive process, stating basic facts like, "I know the area is 270," or "I follow the steps to multiply." These responses suggest that while the students might be aware of the solution procedure, they are not engaging in deeper reflection about why the steps work or how they relate to the problem at hand. In contrast, students who used metacognition reflected more thoroughly on their approach. Responses such as, "the pool is a rectangle, so I will use the formula to find the area because the length of the pool is 27 feet multiplied by the width, which is not there, but it will give 270 square feet as the area," indicate that these students were not only following steps but also reasoning through the problem and explaining the relationships between different variables. This shows a higher level of cognitive engagement and reflective thinking, hallmarks of effective metacognitive strategy use.

The distinction continues in Question 7, which asks about the difficult parts of the problem and the measures taken to overcome them. Non-metacognitive responders offered vague responses such as, "when you multiply a number, it's very hard," or "I find dividing very difficult." These answers suggest that students recognized the challenges but did not engage in meaningful reflection about how to address them. In contrast, metacognitive students provided more insightful responses, such as, "my difficult part is when I multiply 27 and x. I must find the number that represents x, and that is my difficult part." These students not only recognized the challenge but also articulated the specific part of the problem that was causing difficulty. Moreover, they often described steps they took to address these difficulties, such as drawing diagrams or using formulas, demonstrating a more proactive and reflective approach to problem-solving.

Finally, Question 8, which asks about confidence after solving the problem, also highlights the importance of metacognitive reflection. Non-metacognitive students often responded with uncertainty, saying things like, "because I am not sure if it is right or wrong." In contrast, metacognitive students gave more nuanced answers, like, "I think because I'm a little bit confused about the width and height or base, but I predict that my answer will be correct because I understand the problem in my knowledge." Even though this student expresses some uncertainty, their response shows a deeper engagement with the problem and a reflection on how their understanding of key concepts contributed to their solution. This kind of reflective thinking is crucial for developing metacognitive skills and improving future problem-solving performance.

Table 7.
Examples of students' answers.

Question		Example answers
1. How confident are you in solving this problem, in terms of percentage? Why did you choose that number? Please explain the reason.	1	• The problem is too hard • I don't understand the question • I am not sure if my answer will be correct.
	2	• I know a little bit based on what I learnt in our math class
2. What did you consider about strategy while reading the problem?	1	• I don't understand the problem.
	2	• When reading the problem, I notice that one length of the pool is 27 feet, and the width is the x that I will need to work out.
3. What did you understand after reading the problem?	1	• When I read the problem, I got confused • I don't understand how to calculate
	2	• After reading the problem I understand that the length of the swimming pool is 27 feet and that if I find the width of the pool, the total will be 270 square feet. • After reading the problem I know that I must find the width of the pool. • When I read the problem, I know how to find the x and the formula I will use.
5. Explain how you solved the problem.	1	• I just add zero to the 27 and it becomes 270 • I used the formula to calculate area
	2	• I use the formula of rectangle which is L x W. First, we have to find the width which is the x, so 27 times x gives the number of 270. x = 10. So, we go 27 times 10 and it will give you the answer. • First, I take the area (270) and I divide it by length (27) then I find my answer. To be sure weather my answer is correct I get 27 and multiply by 10 and for sure it's 270 which is the area. • How I find the answer I use the formula, Area = Length multiply x, then I multiply 27 x 10 I find the answer is 270.
6. What did you think about while solving the problem?	1	• I know the area is 270 • I follow the steps to multiply.
	2	• I consider that when you started with the formula it's easy for you to calculate or solve the problem they ask for. • The most important thing is to find the width of the swimming pool. • I consider that during solving the problem I see x is represent 10 so I came with 27 x 10 so I see that x is represent 10 so when I multiply, I found my straight answer.
7. Explain the difficult parts when solving the problem. Did you take any measure against them?	1	• When you multiply a number it's very hard • I find dividing very difficult
	2	• My difficult part is when I multiply 27 and x I must find the number that represent x that is my difficult part. • The difficult part is when I must find the missing number of the rectangular pool. I use the formula L x W
8. How confident are you that you solved this problem, in terms of percentage? Why did you choose that number? Please explain the reason.	1	• Because I am not sure if it is right or wrong. • I am sure that my answer is correct
	2	• I think because I'm a little bit confused about the width and height or base but that level which pretty doubting. For overall, I predict that my answer will be correct in a way that I understand the problem in my knowledge.

4. Conclusion

In conclusion, this study provides valuable insights into the role of metacognitive skills in mathematical problem-solving among high school students in the Republic of Vanuatu. The findings revealed that both correct and incorrect responders utilized metacognitive abilities such as self-monitoring, self-regulation, and evaluation. However, the key difference lay in how effectively these skills were applied. Correct responders were more adept at connecting their strategies to prior knowledge and adjusting their approaches when encountering difficulties, demonstrating a more effective use of metacognitive regulation. In contrast, incorrect responders, while actively engaging in metacognitive activities, struggled to apply their reflections to improve problem-solving outcomes, which aligns with prior research suggesting that mere engagement in metacognition is not enough; the quality of reflection is crucial.

The study also highlights the importance of explanatory power—correct responders displayed stronger abilities in articulating their problem-solving strategies, particularly in question 5, which measured metacognitive knowledge related to strategy. This suggests that students who can explain their reasoning are more likely to solve problems successfully, a finding supported by previous studies on the role of explanation in metacognitive development. These examples further illustrate that students who actively reflect on their understanding, relate problems to previously learned material, and consciously monitor and adjust their strategies are more likely to succeed. On the other hand, those who do not use metacognitive strategies tend to struggle with articulating clear plans or solutions and often fail to recognize where they went wrong, reinforcing the need for effective metacognitive instruction.

While the results provide useful directions for enhancing metacognitive instruction in mathematics education, this research is not without limitations. The small sample size from one school in the Republic of Vanuatu may limit the generalizability of the findings. Additionally, the study focused on a single non-routine problem, which may not fully capture the range of metacognitive engagement in different types of mathematical tasks. Future research should aim to include larger and more diverse samples, as well as a broader range of mathematical problems, to better understand the nuances of metacognitive strategy use across contexts.

Despite these limitations, this study contributes to the growing body of research on metacognition in developing countries and offers a framework for assessing and fostering metacognitive skills in mathematics education. By helping students connect new problems to prior knowledge, reflect on their cognitive processes, and adjust their strategies in real time, educators can better equip students to become independent, adaptive problem solvers capable of navigating complex challenges in mathematics and beyond.

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